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Laboratory for Insulation Research
Massachusetts Institute of Technology
Cambridge, MA 02139

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FINAL REPORT AFML-TR-74-250, PART IV
INTERIM REPORT FOR PERIOD JANUARY 1977 - MAY 1980

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MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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The main body of this report lists dielectric constant and loss data on materials measured in this laboratory in the period 1 July 1977 through 15 May 1980 together with measurements techniques and calculations.

The index following the data section is intended to be a complete reference to dielectric measurement data of this laboratory to date.

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PREFACE

The dielectric constant and loss data presented in this report were measured at the Laboratory for Insulation Research of the Massachusetts Institute of Technology, Cambridge, Massachusetts, by W. B. Westphal. This work was performed between 1 January 1977 and 15 May 1980 under Contract F33615-77-C-5063, Project No. 7514, Task No. 24230104 for the Materials Laboratory of the Air Force Wright Aeronautical Laboratories.

This report was submitted by the author for publication in August 1980.

The work was administered under direction of the AF Materials Laboratory, with Mr. John C. Olson (AFWAL/MLPJ) acting as project engineer.

TABLE OF CONTENTS

SUMMARY

The first sections of this report describe changes in measurement techniques and programming of calculations.

A technical report dated December 1975 presents data on materials measured in the early part of this contract. A later data report is dated May 1977. The index following the data section refers to early data reports and uses the prefix 10- for pages of the present report.

The data section does not generally include measurements on research samples under development by or for the Air Force Materials Laboratory.

MEASUREMENT TECHNIQUE

The basic measurement techniques using bridges, reentrant cavities, standing waves, and dielectric-filled cavities have been discussed in previous reports.[1-7*] During the present contract period the only new type of measurements has been for high loss liquids: the use of a glass or plastic capillary tube mounted in a plane one-quarter wavelength from the short in the standing wave system. The tube axis is parallel to the electric field in either rectangular or circular hollow waveguide. This method was used for water-acid solutions, liquid ammonia and sulfur.

PROGRAMMING

Program 1,in the following section, is used for calculating the dielectric constant and loss of a sample in a capillary tube. The input data:

DS	node width, sample in
SN	node position, sample in
CONC	specified acid concentration
NC	number of measurements
DG	node width, empty capilliary
GN	node position, empty capilliary
R	inner radius of capilliary
FGH	frequency, GHz
C	conversion factor between capilliary admittance and waveguide admittance at the same plane
C1	initial guess for correction term in K1 due to loss, Iteration finds exact correction
WLG	wavelength in air filled waveguide
SMF	conversion factor to calculate conductivity from loss factor

*<u>References</u>

1. Tech. Rep. 182 Lab. Ins. Res., Contract AF33(616)-8353, October 1963.
2. " " 201 " " " " " October 1966.
3. AFML-TR-66-28, " " " " AF33(615)-2199, January 1966.
4. AFML-TR-70-138, " " " " F33615-67C-1612, July 1970.
5. AFML-TR-71-66, " " " " F33615-70C-1220, April 1971.
6. AFML-TR-74-250, Pt. II, Lab. Ins. Res., Contract F33615-71-C-1274, December 1975
7. AFML-TR-74-250, Pt. III, " " " Contract F33615-75-C-5020, May 1977

Program 1 High Loss Liquid in Capilliary

```
FORTRAN IV G1  RELEASE 2.0

0001             REAL*8 TWO,WL,FGH,PII3,PII4,WLG,XOG,DELN,TANG,EG,DG,XOS,GN,SN,
                2TANS,THETA,DS,ES,K1M,K2M,K1,K2,C1,KM,KMA,KMB,K1CAL,K2CAL,ERROR,
                3WE,K1OLD,K2OLD,EROLD,SMF,SIGMA,CONC,R,C,STEP(4)/.03D0,.01D0,
                4.003D0,.001D0/,F(2)/1.D0,-1.D0/,FAKE(2),FUN(2),ONE
0002             COMPLEX*16 ZONE,ZOONE,TWOC,YG,YT,KMAC,KMBC,GR,D2C,D3C,D4C,D5C,
                2D6C,D7C,J11,J12,J13,J14,J1,J01,J02,J03,J04,J0,RATIO,K1C,K2C,KCOR,
                3YG1,YG2,YG3,YG4,YT2,YT3,YT4,YS,KC
0003             EQUIVALENCE (FAKE(1),YS),(FUN(1),KCOR)
0004             DIMENSION DS(40),SN(40),CONC(40),DATE(39)
0005             NAMELIST/IN/DS,SN,CONC,NC/CONST/DG,GN,DELN,R,FGH,C,C1,WLG,SMF
0006         200 FORMAT (1X,39A2)
0007         201 FORMAT(1H0,20X,39A2,/)
0008         100 FORMAT(1X,7HWT%ACID,5X,2HK1,3X,9HUNCOR. K1,5X,2HK2,3X,
                29HUNCOR. K2,3X,12HSIGMA MHO/CM,1X,5HERROR,10X,3HJ04,10X,3HJ14)
0009         101 FORMAT(F7.3,1X,F8.2,1X,F8.2,3X,F8.2,2X,F8.2,3X,F9.5,1X,
                2E9.2,1X,E9.2,1X,E9.2 1X,E9.2,1X,E9.2)
0010         102 FORMAT(5X,2HDS,10X,2HSN,10X,4HCONC,8X,1HI)
0011         103 FORMAT(1X,F10.4,1X,F10.4,1X,F10.4,8X,I2)
0012         104 FORMAT(3X,13HKOUNT FOR K1=,1X,I2)
0013         105 FORMAT(3X,13HKOUNT FOR K2=,1X,I2)
0014          77 READ(5,200,END=88) DATE
0015             WRITE(6,201) DATE
0016             READ(5,IN)
0017             READ(5,CONST)
0018             WRITE(6,102)
0019             DO 8 I=1,NC
0020             WRITE(6,103) DS(I),SN(I),CONC(I),I
0021           8 CONTINUE
0022             ZONE=(1.D0,0.D0)
0023             ZOONE=(0.D0,1.D0)
0024             ONE=1.D0
0025             TWO=2.D0
0026             TWOC=ZONE*TWO
0027             WL=2.997924562D1/FGH
0028             PII3=6.2831853072D0/WL
0029             PII4=6.283180D0/WLG
0030             WRITE(6,CONST)
0031             WRITE(6,100)
0032             XOG=WLG/4.D0-DELN
0033             TANG=DTAN(PII4*XOG)
0034             EG=PII4*DG/TWO
0035             YG=(ZOONE*(-C))*(ZONE-ZOONE*(EG*TANG))/((ZONE*EG)-(ZOONE*TANG))
0036             DO 10 I=1,NC
0037             XOS=XOG-(GN-SN(I))
0038             TANS=DTAN(PII4*XOS)
0039             THETA=PII4*DS(I)/TWO
0040             ES=DSIN(THETA)/DSQRT(TWO-(DCOS(THETA))**2)
0041             YT=(ZOONE*(-C))*(ZONE-ZOONE*(ES*TANS))/((ZONE*ES)-(ZOONE*TANS))
0042             YS=YT-YG
0043             K1M=FAKE(1)
0044             K2M=-FAKE(2)
0045             K1M=K1M+ONE
0046             K1=K1M+C1*K2M
0047             K2=K2M
0048             KM=DSQRT(K1**2+K2**2)
0049             KMA=DSQRT((KM-K1)/TWO)*PII3*R
0050             KMB=DSQRT((KM+K1)/TWO)*PII3*R
0051             KMAC=ZONE*KMA
0052             KMBC=ZOONE*KMB
0053             GR=KMBC+KMAC
0054             D2C=ZONE*16.D0
0055             D3C=ZONE*384.D0
0056             D4C=ZONE*1.8432D4
0057             D5C=ZONE*4.D0
0058             D6C=ZONE*64.D0
0059             D7C=ZONE*2304.D0
0060             J11=GR/TWOC
0061             J12=GR**3/D2C
0062             J13=GR**5/D3C
0063             J14=GR**7/D4C
```

```
      J1=J11+J12+J13+J14
      J01=ZONE
      J02=GR**2/D5C
      J03=GR**4/D6C
      J04=GR**6/D7C
      J0=J01+J02+J03+J04
      RATIO=(TWOC/GR)*J1/J0
      K1C=ZONE*K1
      K2C=ZOONE*(-K2)
      KC=K1C+K2C
      KCOR=KC*RATIO
      K1CAL=FUN(1)
      K2CAL=-FUN(2)
      ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
      DO 400 K=1,4
      DO 600 J=1,2
      WE=ONE+STEP(K)*F(J)
      KOUNT=0
  401 K1OLD=K1
      KOUNT=KOUNT+1
      EROLD=ERROR
      K1=K1*WE
      KM=DSQRT(K1**2+K2**2)
      KMA=DSQRT((KM-K1)/TWO)*PII3*R
      KMB=DSQRT((KM+K1)/TWO)*PII3*R
      KMAC=ZONE*KMA
      KMBC=ZOONE*KMB
      GR=KMBC+KMAC
      D2C=ZONE*16.D0
      D3C=ZONE*384.D0
      D4C=ZONE*1.8432D4
      D5C=ZONE*4.D0
      D6C=ZONE*64.D0
      D7C=ZONE*2304.D0
      J11=GR/TWOC
      J12=GR**3/D2C
      J13=GR**5/D3C
      J14=GR**7/D4C
      J1=J11+J12+J13+J14
      J01=ZONE
      J02=GR**2/D5C
      J03=GR**4/D6C
      J04=GR**6/D7C
      J0=J01+J02+J03+J04
      RATIO=(TWOC/GR)*J1/J0
      K1C=ZONE*K1
      K2C=ZOONE*(-K2)
      KC=K1C+K2C
      KCOR=KC*RATIO
      K1CAL=FUN(1)
      K2CAL=-FUN(2)
      ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
      IF(KOUNT.GT.20) GO TO 601
      IF(ERROR.LE.EROLD) GO TO 401
      K1=K1OLD
      ERROR=EROLD
  600 CONTINUE
      GO TO 602
  601 WRITE(6,104) KOUNT
  602 DO 700 J=1,2
      WE=ONE+STEP(K)*F(J)
      KOUNT=0
  421 K2OLD=K2
      KOUNT=KOUNT+1
      EROLD=ERROR
      K2=K2*WE
      KM=DSQRT(K1**2+K2**2)
      KMA=DSQRT((KM-K1)/TWO)*PII3*R
      KMB=DSQRT((KM+K1)/TWO)*PII3*R
```

Program 1, continued

```
                  GR=KMBC+KMAC
                  D2C=ZONE*16.D0
                  D3C=ZONE*384.D0
                  D4C=ZONE*1.8432D4
                  D5C=ZONE*4.D0
                  D6C=ZONE*64.D0
                  D7C=ZONE*2304.D0
                  J11=GR/TWOC
                  J12=GR**3/D2C
                  J13=GR**5/D3C
                  J14=GR**7/D4C
                  J1=J11+J12+J13+J14
                  J01=ZONE
                  J02=GR**2/D5C
                  J03=GR**4/D6C
                  J04=GR**6/D7C
                  J0=J01+J02+J03+J04
                  RATIO=(TWOC/GR)*J1/J0
                  K1C=ZONE*K1
                  K2C=ZOONE*(-K2)
                  KC=K1C+K2C
                  KCOR=KC*RATIO
                  K1CAL=FUN(1)
                  K2CAL=-FUN(2)
                  ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
                  IF(KOUNT.GT.20) GO TO 701
                  IF(ERROR.LE.EROLD) GO TO 421
                  K2=K2OLD
                  ERROR=EROLD
              700 CONTINUE
                  GO TO 702
              701 WRITE(6,105) KOUNT
              702 IF(ERROR.LE.1.D-4) GO TO 450
              400 CONTINUE
              450 SIGMA=SMF*K2
                  WRITE(6,101) CONC(I),K1,K1M,K2,K2M,SIGMA,ERROR,J04,J14
               10 CONTINUE
                  GO TO 77
               88 CALL EXIT
                  END
```

Output

```
                3GHZ 21.3 DEG.C.

DS           SN           CONC           I
0.0679       0.3032       0.0            1
0.2009       0.3159       1.1090         2
0.6445       0.3835       5.0434         3
1.1360       0.5070       10.0760        4
&CONST
DG=  .12000000000000002D-01,GN=  .47999999999999996    ,DELN=  .21970000000000006

R=  .32173000000000002D-01,FGH= 3.0000000000000000    ,C=  938.39999999999977   ,
C1=  .15700000000000004D-01,WLG=  13.855000000000000    ,SMF= .16666599999999998D-02
&END

 WT%ACID     K1    UNCOR. K1      K2    UNCOR. K2    SIGMA MHO/CM  ERROR
  0.0      77.45     77.73      12.24      12.34       0.02041   0.24D-01
  1.109    71.70     71.84      41.14      41.43       0.06856   0.33D-01
  5.043    40.68     39.82     134.86     135.40       0.22477   0.19D-01
 10.076   -12.93    -15.64     231.21     230.75       0.38534   0.11D+00
                                                   J04              J14
                                        -0.13D-07  0.65D-08 -0.17D-09 -0.27D-09
                                        -0.11D-09  0.17D-07 -0.37D-09  0.97D-10
                                         0.64D-07 -0.53D-07  0.24D-08  0.59D-09
                                        -0.62D-07 -0.37D-06  0.79D-08 -0.12D-07
```

Program 2 is used for calculating the results for a temperature run on a thin sample (in coax or hollow waveguide) located on a quarter-wavelength spacer. The variations in data with temperature of the empty sample holder with, and without, the spacer are expressed as a power series of temperature change from room temperature. Corrections can then be made for the change in electrical length of the spacer with temperature. Partial notation follows:

DXQC	node width for holder with spacer only, corrected for temperature effects
DAC	node width for empty holder corrected for temperature
ANC	node position for empty holder versus temperature
QNC	node position for holder with spacer only corrected for changes with temperature
DQC	spacer length versus temperature
THC	sample thickness corrected for linear thermal expansion

Program 2. Thin Sample temp. run

FORTRAN IV G1 RELEASE 2.0

```
                INTEGER*4 I,J,K,N,NX
                REAL*8 PII,PII2,ONE,TWO,W,FC,W1,TANW1,DA,DT,THC,D,T,T0,TCD,LW02,
               2LW,WL2,WC2,WC1,C2,TC6,K3,TANW2,TCW,DQC,DQ,TCQ,DAC,A5,A6,DXQC,
               3DXQ,AQ,AQQ,DXQCC,QN,AN,TC1,TC2,TC3,ANC,QNC,TC7,TC8,TC9,TXOQ,
               4W2,PII3,U,TA1,DC,DX,SN,COSINE,TXOS,Z11RE,Z11IM,SILLY(2),AZ11,
               5AZ16,A,B,FUN(2),TAHA,TANB,A2,B2,Z14RE,Z14IM,ERROR1,WE,BOLD,
               6STEP(5)/1.D-2,1.D-3,1.D-4,1.D-5,1.D-6/,F(2)/1.D0,-1.D0/,Z14IOD,
               7Z14ROD,EROLD,AOLD,FCC,FAKE(2),RA,AIM,C1,TC6,C2C,C2,KAPPA,TAND,L1,
               8L2,L3,R,KAPPAC,TANDC,RE,TAM,SIGMA,PUN(2),DS,C1C,D2,D3,AX,WL1
                COMPLEX*16 ZONE,ZOONE,X,Y,Z32,AL1D2,BE1D2,G1D2,Z4,Z10,Z11,Z16,
               2Z12SQ,THG2D2,Z14,Z12RE,Z12IM,Z12NEW,Z13,G,H,Z15,Z17,G2D2,K3C,Z14R,
               3Z14I
                DIMENSION DS(30),SN(30),D2(30),D3(30),DATE(39),AX(30),T(30)
                EQUIVALENCE (SILLY(1),Z4),(FAKE(1),Z15),(FUN(1),Z14),
               2(PUN(1),Z12SQ)
                NAMELIST/CONST/DA,DXQ,DQ,FC,LW,DT,TCW,TCQ,A5,A6,AQ,AQQ,TC1,TC2,T0,
               2TC3,TC7,TC8,TC9,TCD,TC6,C1,C2,D,AN,QN/IN/DS,SN,T,D2,D3,AX,
               3NX/OUT/A,B,AZ11,AZ16,Z12SQ,Z11,Z16
            200 FORMAT(1X,39A2)
            201 FORMAT(1H0,20X,39A2)
            220 FORMAT(1H0,5X,2HDS,8X,2HSN,6X,2HD2,7X,2HD3,7X,2HAX,8X,
               24HTEMP,6X,1HI)
            230 FORMAT(2X,F8.4,1X,F8.4,2X,F7.4,2X,F6.4,2X,F8.5,2X,F8.2,2X,I2)
            100 FORMAT(1H0,5X,2HNS,6X,2HDS,4X,7HD,CORR.,4X,2HFC,6X,1HB,6X,2HK1,
               29X,2HK2,9X,3HTAN,15X,6HZ4/Z14//)
            300 FORMAT(2X,F7.4,2X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,3X,F9.6,
               23X,F9.6,3X,E13.6,2X,E13.6)
            301 FORMAT(10X,6HTEMP.=,F7.1,1X,6HDEG.C.,4X,6HSIGMA=,E11.4,6HMHO/CM,
               25X,19HSAMPLE HOLDER DIA.=,F8.5)
             77 READ(5,200,END=88) DATE
                WRITE(6,201) DATE
                READ(5,CONST)
                READ(5,IN)
                WRITE(6,220)
                WRITE(6,230)(DS(I),SN(I),D2(I),D3(I),AX(I),T(I),I,I=1,NX)
                WRITE(6,CONST)
                WRITE(6,100)
                ZONE=(1.D0,0.D0)
                ZOONE=(0.D0,1.D0)
                ONE=1.D0
```

Program 2, continued

```
      TWO=2.D0
      PII=3.14159265360D0
      PII2=TWO*PII
      W=ONE+FC
      W1=W
      TANW1=DA/(DT*W1)
      WL1=LW
      LW02=LW**2/W
      DO 10 I=1,NX
      THC=D*(ONE+(T(I)-TO)*TCD)
      IF(FC.GT.0.D0) GO TO 33
      WL2=LW
      WC2=1.D30
      GO TO 35
   33 WC1=3.412586D0*1.27D0*C2
      WC2=WC1*(ONE+TC6*(T(I)-TO))
      WL2=DSQRT(LW02*WC2**2/(WC2**2-LW02))
   35 K3=WL2/(PII2*THC)
      W2=(WL2/WC2)**2+ONE
      TANW2=TANW1*DSQRT(ONE+TCW*(T(I)-TO))*W1/W2
      DQC=DQ*(ONE+TCQ*(T(I)-TO))
      DAC=DA*(ONE+A5*(T(I)-TO)+A6*(T(I)-TO)**2)
      DXQC=DXQ*(ONE+AQ*(T(I)-TO)+AQQ*(T(I)-TO)**2)
      DXQCC=DXQC-DAC-(QN-AN)*W1*TANW1+DQC*W2*TANW2
      ANC=AN-TC1*(T(I)-TO)-TC2*(T(I)-TO)**TC3
      QNC=QN-TC7*(T(I)-TO)-TC8*(T(I)-TO)**TC9
      TXOQ=DTAN(PII2*((QNC-ANC)/WL1-DQC/WL2))
      X=ZONE*(DXQCC*PII/WL2)
      Y=ZOONE*(-TXOQ)
      ZB2=(X+Y)/(ZONE+X*Y)
      PII3=PII2/WL2
      U=W2-ONE
      TA1=DSQRT(ONE+(TANW2/(ONE-U/(1.00054D0+W2)))**2)
      AL1D2=ZONE*(PII3*DSQRT(5.D-1*(1.00054*W2-U)*(TA1-ONE))*THC)
      BE1D2=ZOONE*(PII3*DSQRT(5.D-1*(1.00054*W2-U)*(TA1+ONE))*THC)
      G1D2=AL1D2+BE1D2
      DC=DQC+THC
      DX=DS(I)-DXQC-(SN(I)-QN)*W1*TANW1+DC*W2*TANW2
      COSINE=DCOS(PII*DX/WL2)**2
      X=DSIN(PII*DX/WL2)/DSQRT(AX(I)-COSINE)
      TXOS=DTAN(PII2*((SN(I)-ANC)/WL1-DC/WL2))
      Y=ZOONE*(-TXOS)
      Z4=(X+Y)/(ZONE+X*Y)
      Z10=ZOONE/K3
      Z11=Z10/Z4
      Z11RE=SILLY(1)
      Z11IM=SILLY(2)
      Z16=(1.D0/3.D0)*Z11**2
      Z12SQ=CDSQRT(Z11+Z16)
      AZ11=CDABS(Z11)
      AZ16=CDABS(Z16)
      A=PUN(1)
      B=PUN(2)
      IF(0.D0.LT.B) GO TO 160
      WRITE(6,OUT)
      B=1.D0
  160 TAHA=DTANH(A)
      TANB=DTAN(B)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      THG2D2=ZONE*A2+ZOONE*B2
      G2D2=ZONE*A+ZOONE*B
      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
      Z14RE=FUN(1)
      Z14IM=FUN(2)
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
```

Program 2, continued

```
      DO 400 K=1,5
      TAHA=DTANH(A)
      DO 600 J=1,2
      WE=ONE+STEP(K)*F(J)
  401 BOLD=B
      Z14IOD=Z14IM
      Z14ROD=Z14RE
      EROLD=ERROR1
      B=B*WE
      TANB=DTAN(B)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      THG2D2=ZONE*A2+ZOONE*B2
      G2D2=ZONE*A+ZOONE*B
      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
      Z14RE=FUN(1)
      Z14IM=FUN(2)
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
      IF(ERROR1.LE.EROLD) GO TO 401
      Z14IM=Z14IOD
      Z14RE=Z14ROD
      B=BOLD
      ERROR1=EROLD
  600 CONTINUE
      TANB=DTAN(B)
      DO 700 J=1,2
      WE=ONE+STEP(K)*F(J)
  402 AOLD=A
      Z14ROD=Z14RE
      Z14IOD=Z14IM
      EROLD=ERROR1
      A=A*WE
      TAHA=DTANH(A)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      THG2D2=ZONE*A2+ZOONE*B2
      G2D2=ZONE*A+ZOONE*B
      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
      Z14RE=FUN(1)
      Z14IM=FUN(2)
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
      IF(ERROR1.LE.EROLD) GO TO 402
      Z14RE=Z14ROD
      Z14IM=Z14IOD
      A=AOLD
      ERROR1=EROLD
  700 CONTINUE
      IF(ERROR1.LE.1.D-6) GO TO 450
  400 CONTINUE
  450 Z12RE=ZONE*A
      Z12IM=ZOONE*B
      Z12NEW=(Z12RE+Z12IM)**2
      K3C=K3*ZONE

      Z13=-Z12NEW*K3C**2
      FCC=U
      G=ZONE*FCC
      H=ZONE*W2
      Z15=(G+Z13)/H
      Z14R=ZONE*Z14RE
      Z14I=ZOONE*Z14IM
      Z14=Z14R+Z14I
      Z17=Z4/Z14
      RA=FAKE(1)
      AIM=-FAKE(2)
      C1C=C1*(ONE+(T(I)-T0)*TC6)
      C2C=C2*(ONE+(T(I)-T0)*TC6)
      KAPPA=FAKE(1)
      TAND=AIM/RA
      IF(FC.GT.0.D0) GO TO 210
```

Program 2, continued

```
                  L1=DLOG10(D2(I)/C1C)+DLOG10(C2C/D3(I))
                  L2=DLOG10(D3(I)/D2(I))
                  L3=DLOG10(C2C/C1C)
                  R=ONE-L1*KAPPA*(ONE+TAND**2)/L3
                  KAPPAC=R*KAPPA/((L3/L2)-TWO*L1*KAPPA/L2+(ONE-R)*L1*KAPPA/L2)
                  TANDC=TAND/R
                  RE=KAPPAC
                  TAM=TANDC-TANW2
                  AIM=RE*TAM
                  GO TO 15
              210 RE=RA+8368.D-4*(RA**2-RA)*(C2C-D3(I))/C2C
               18 TAM=AIM/RE-TANW2*(4.2D-1+W2/RA)/(4.2D-1+W2)
                  AIM=RE*TAM
               15 WRITE(6,300) ANC,DX,THC,FCC,B,RE,AIM,TAM,Z17
                  SIGMA=1.6669198D-2*AIM/DSQRT(LW02)
                  WRITE(6,301) T(I),SIGMA,C2C
               10 CONTINUE
                  GO TO 77
               88 CALL EXIT
                  END
```

Output

```
                      RAYTHEON POLYIMIDE LAMINATE (OAK) TEMP. RUN   8-3-79

     DS         SN       D2        D3        AX          TEMP        I
   0.0233     5.4206    0.0      0.9948    2.00000      24.00    1
   0.0263     5.3965    0 0      0.9951    2.00000      52.00    2
   0.0251     5.3842    0.0      0.9953    2.00000      77.00    3
   0.0280     5.3681    0.0      0.9956    2.00000     100.00    4
&CONST
DA=  .6000000000000000012D-02,DXQ=  .7199999999999999980D-02,
  5.9926999999999992      ,DT=  21.000000000000000     ,
  .4000000000000000019D-03,A6=  .0                     ,
  .4827599999999999993D-03,TC2=  .3533000000000000000D-08,
  .6209000000000000001D-04,TC8= -.5851900000000000023D-09,
  .1942999999999999986D-04,C1=  .37450000000000000      ,
  6.1597999999999994      ,QN=  5.9591000000000006
&END

                         DQ=  1.2876000000000008     ,FC=  1.9006000000000007     ,LW=
                      TCW=  .4000000000000000008D-02,TCQ=  .5400000000000000005D-06,A5=
                      AQ=  .1500000000000000000D-03,AQQ=  .0                         ,TC1=
                       T0=  24.000000000000000      ,TC3=  2.5000000000000000      ,TC7=
                       TC9=  3.0000000000000000      ,TCD=  .9999999999999999997D-05,TC6=
                      C2=  1.0027999999999991      ,D=  .6650000000000000036D-01,AN=

   NS        DS       D,CORR.      FC        B        K1           K2


6.1596    0.0166   0.0665   1.9025   0.2238   4.2987      0.059233
      TEMP.=     24.0 DEG.C.      SIGMA= 0.2806D-03MHO/CM
6.1463    0.0196   0.0665   1.8965   0.2286   4.4583      0.072164
      TEMP.=     52.0 DEG.C.      SIGMA= 0.3419D-03MHO/CM
6.1341    0.0194   0.0665   1.8912   0.2306   4.5282      0.071714
      TEMP.=     77.0 DEG.C.      SIGMA= 0.3397D-03MHO/CM
6.1229    0.0213   0.0666   1.8863   0.2336   4.6312      0.080035
      TEMP.=    100.0 DEG.C.      SIGMA= 0.3792D-03MHO/CM
                                                  TAN                    Z4/Z14

                                                      0.013779    0.100000D+01    0.166215D-07
                                                  SAMPLE HOLDER DIA.= 1.00280
                                                      0.016187    0.999999D+00   -0.248313D-08
                                                  SAMPLE HOLDER DIA.= 1.00335
                                                      0.015837    0.100000D+01    0.804382D-09
                                                  SAMPLE HOLDER DIA.= 1.00383
                                                      0.017282    0.100000D+01    0.402349D-08
                                                  SAMPLE HOLDER DIA.= 1.00428
```

Program 3 is the latest version for calculating a temperature run for a sample at the bottom of the sample holder. It includes a correction for the fact that a node shift in the hot zone of hollow wave-guide does not result in an equal shift in the cold slotted section because the guide wavelengths are different in the two zones. The changes appear in statements 43-47, and 174 in the following program.

Program 3 Shorted Line Temperature Run

```
FORTRAN IV G1  RELEASE 2.0

0001           INTEGER*4 I,J,K,N,NX,KOUNT,COUNT
0002           REAL*8 K3,Y,XE,AN,SN,LW,DX,DS,DA,X,A,B,A2,B2,Z14RE,Z14IM,TWO,
              2BOLD,Z14IOD,Z14ROD,ERROR1,EROLD,AOLD,AIM,RE,TAM,Z11RE,Z11IM,WE,
              9KAPPA,KAPPAC,L1,L2,L3,R,TAND,TANDC,D2,D,D3,SNC,TC1,T,T0,TC2,TC3,
              3COSINE,FC,W,ZM,Y1,TAHA,TANB,PII,PII2,ZRC,ONE,STEP(22)/1.5D-2,
              41.2D-2,
              41.D-2,7.D-3,5.D-3,2.D-3,1.D-3,5.D-4,2.D-4,1.D-4,5.D-5,2.D-5,
              51.D-5,
              55.D-6,2.D-6,1.D-6,1.D-7,1.D-8,1.D-9,1.D-10,1.D-11,1.D-12/,ND8,
              6F(2)/1.D0,-1.D0/,SOLD,RA,TANW,DC,DD0,DD,TC4,TC5,WC1,WC2,TC6,LW02,
              7WL2,DDA,A5,A6,C1,C2,C1C,C2C,FCC,SIGMA,AX,TCD
0003           COMPLEX*16 Z1,Z2,Z3,Z9,Z10,Z11,Z12,Z13,Z14R,Z14I,Z16,K3C,
              2Z14,Z12NEW,Z12RE,Z12IM,Z12SQ,G,H,Z15,Z2A,ZONE,ZOONE
0004           REAL*8 SILLY(2),FAKE(2)
0005           EQUIVALENCE (SILLY(1),Z11),(FAKE(1),Z15)
0006           DIMENSION DS(30),SN(30),D(30),D2(30),D3(30),N(30),DATE(39),
              2T(30),DD(30),AX(30),SIGMA(30),C2C(30)
0007           NAMELIST/IN/DS,SN,N,NX,D,D2,D3,T,DD,AX/CONST/DA,AN,FC,LW,TANW,
              2TC2,TC3,T0,DD0,TC4,TC5,A5,A6,C1,C2,TC6,TC1,TCD
0008       200 FORMAT(1X,39A2)
0009       201 FORMAT(1H0,20X,39A2)
0010       220 FORMAT(1H0,5X,2HDS,8X,2HSN,6X,1HD,7X,2HD2,7X,2HD3,6X,1HN,
              26X,2HDD,4X,11HTEMP.DEG.C.)
0011       230 FORMAT(2X,F8.4,1X,F8.4,2X,F7.4,2X,F6.4,2X,F8.5,2X,I2,2X,F8.4,
              22X,F8.2)
0012       100 FORMAT(1H0,5X,2HNS,6X,2HDS,4X,7HD,CORR.,4X,2HFC,6X,1HB,6X,2HK1,
              29X,2HK2,9X,3HTAN,15X,7HZ11/Z14//)
0013       300 FORMAT(2X,F7.4,2X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,3X,F9.6,
              23X,F9.6,3X,E13.6,2X,E13.6)
0014       301 FORMAT(9X,6HDEG.C. 4X,8HSIGMA IN,1X,6HMHO/CM,1X,
              220HSAMPLE HOLDER DIA.'')
0015       302 FORMAT(10X,F7.1,4X,E11.4,10X,F8.5)
0016        77 READ(5,200,END=98) DATE
0017           WRITE(6,201) DATE
0018           READ(5,IN)
0019           READ(5,CONST)
0020           WRITE(6,220)
0021           WRITE(6,230)(DS(I),SN(I),D(I),D2(I),D3(I),N(I),DD(I),T(I),I=1,NX)
0022           WRITE(6,CONST)
0023           WRITE(6,100)
0024           ZONE=(1.D0,0.D0)
0025           ZOONE=(0.D0,1.D0)
0026           ONE=1.D0
0027           TWO=2.D0
0028           PII=3.14159265360D0
0029           PII2=PII*TWO
0030           ZRO=0.D0
0031           DO 10 I=1,NX
0032           IF(DD(I).EQ.DD0) GO TO 22
0033           DC=D(I)+(DD0-DD(I))*2.54D0+TC4*(T(I)-T0)+TC5*(T(I)-T0)**2
0034           GO TO 23
0035        22 DC=D(I)*(ONE+(T(I)-T0)*TCD)
0036        23 SNC=SN(I)+(TC1*(T(I)-T0)+TC2*(T(I)-T0)**TC3)
```

Program 3, continued

```
      W=ONE+FC
      LWO2=LW**2/W
      IF(FC.GT.0.D0) GO TO 33
      WL2=LW
      WC2=1.D30
      GO TO 35
   33 WC1=3.412586D0*1.27D0*C2
      WC2=WC1*(ONE+TC6*(T(I)-T0))
      WL2=DSQRT(LWO2*WC2**2/(WC2**2-LWO2))
   35 K3=WL2/(PII2*DC)
      Y=PII2*((SNC-AN)/LW-DC/WL2)
      DDA=DA*(ONE+A5*(T(I)-T0)+A6*(T(I)-T0)**2)
      DX=DS(I)-DDA
      IF(DX.LE.ZRO) GO TO 10
      COSINE=DCOS(PII*DX/LW)**2
      X=DSIN(PII*DX/LW)/DSQRT(AX(I)-COSINE)
      Y1=DTAN(Y)
      Z1=ZOONE*Y1
      Z2A=ZONE*X
      Z2=Z2A-Z1
      Z3=ZONE-Z2A*Z1
      Z9=Z2/Z3
      Z10=ZOONE*(-K3)
      Z11=Z10*Z9
      Z11RE=SILLY(1)
      Z11IM=SILLY(2)
      ZM=DSQRT(Z11RE**2+Z11IM**2)
      IF(N(I) .EQ. 1) GO TO 141
      IF(N(I) .GE. 2) GO TO 142
  141 IF(ZM.LE.ONE.AND.Z11RE.GE.ZRO) GO TO 150
      IF(ZM.LE.ONE.AND.Z11RE.LT.ZRO) GO TO 151
      IF(ZM.GT.ONE.AND.Z11RE.GE.ZRO) GO TO 152
      IF(ZM.GT.ONE.AND.Z11RE.LT.ZRO) GO TO 153
  142 IF(ZM.LE.ONE.AND.Z11RE.GE.ZRO) GO TO 170
      IF(ZM.LE.ONE.AND.Z11RE.LT.ZRO) GO TO 171
      IF(ZM.GT.ONE.AND.Z11RE.GE.ZRO) GO TO 172
      IF(ZM.GT.ONE.AND.Z11RE.LT.ZRO) GO TO 173
  150 B=ONE
      A=42.D-1*DX/LW
      GO TO 160
  151 B=22.D-1
      A=2.D0*DX/LW
      GO TO 160
  152 B=ONE
      A=6.D0*DX/LW
      GO TO 160
  153 B=18.D-1
      A=DX/LW
      GO TO 160
  170 ND8=N(I)
      B=(ND8-ONE)*PII+7854.D-4
      A=4.D0*DX/LW
      GO TO 160
  171 ND8=N(I)
      B=ND8*PII-7854.D-4
      A=4.D0*DX/LW
      GO TO 160
  172 ND8=N(I)
      B=(2.D0*ND8-1.D0)*15708.D-4-2.D-1/ND8
      A=DX/LW
      GO TO 160
  173 ND8=N(I)
      B=(2.D0*ND8-1.D0)*15708.D-4+2.D-1/ND8
      A=DX/LW
  160 TAHA=DTANH(A)
      TANB=DTAN(B)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      Z14RE=(A*A2+B*B2)/(A**2+B**2)
      Z14IM=(A*B2-B*A2)/(A**2+B**2)
```

Program 3, continued

```
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
      COUNT=0
  440 COUNT=COUNT+1
      DO 400 K=1,22
      SOLD=STEP(K)
      TAHA=DTANH(A)
      DO 600 J=1,2
  420 WE=ONE+STEP(K)*F(J)
      KOUNT=0
  401 KOUNT=KOUNT+1
      IF(KOUNT.GT.10.AND.STEP(K).LE.1.D-3) GO TO 411
      GO TO 425
  411 STEP(K)=STEP(K)*10.D0
      GO TO 420
  425 BOLD=B
      Z14IOD=Z14IM
      Z14ROD=Z14RE
      EROLD=ERROR1
      B=B*WE
      TANB=DTAN(B)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      Z14RE=(A*A2+B*B2)/(A**2+B**2)
      Z14IM=(A*B2-B*A2)/(A**2+B**2)
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
      IF(ERROR1.LE.EROLD) GO TO 401
      Z14IM=Z14IOD
      Z14RE=Z14ROD
      B=BOLD
      ERROR1=EROLD
      STEP(K)=SOLD
  600 CONTINUE
      TANB=DTAN(B)
      DO 700 J=1,2
  421 WE=ONE+STEP(K)*F(J)
      KOUNT=0
  402 KOUNT=KOUNT+1
      IF(KOUNT.GT.10.AND.STEP(K).LE.1.D-3) GO TO 412
      GO TO 428
  412 STEP(K)=STEP(K)*10.D0
      GO TO 421
  428 AOLD=A
      Z14ROD=Z14RE
      Z14IOD=Z14IM
      EROLD=ERROR1
      A=A*WE
      TAHA=DTANH(A)
      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
      Z14RE=(A*A2+B*B2)/(A**2+B**2)
      Z14IM=(A*B2-B*A2)/(A**2+B**2)
      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
      IF(ERROR1.LE.EROLD) GO TO 402
      Z14RE=Z14ROD
      Z14IM=Z14IOD
      A=AOLD
      ERROR1=EROLD
      STEP(K)=SOLD
  700 CONTINUE
      IF(ERROR1.LE.1.D-7) GO TO 450
  400 CONTINUE
      IF(ERROR1.GT.1.D-7.AND.COUNT.LE.2) GO TO 440
  450 Z12RE=ZONE*A
      Z12IM=ZDONE*B
      Z12NEW=(Z12RE+Z12IM)**2
      K3C=K3*ZONE
      Z13=-Z12NEW*K3C**2
      FCC=WL2**2/WC2**2
      W=ONE+FCC
      G=ZONE*FCC
```

Program 3, continued

```
      H=ZONE+W
      Z15=(G+Z13)/H
      Z14R=ZONE*Z14RE
      Z14I=ZOONE*Z14IM
      Z14=Z14R+Z14I
      Z16=Z11/Z14
      RA=FAKE(1)
      AIM=-FAKE(2)
      C1C=C1*(ONE+(T(I)-T0)*TC6)
      C2C(I)=C2*(ONE+(T(I)-T0)*TC6)
      KAPPA=FAKE(1)
      TAND=AIM/RA
      IF(FC.GT.0.D0) GO TO 210
      L1=DLOG10(D2(I)/C1C)+DLOG10(C2C(I)/D3(I))
      L2=DLOG10(D3(I)/D2(I))
      L3=DLOG10(C2C(I)/C1C)
      R=ONE-L1*KAPPA*(ONE+TAND**2)/L3
      KAPPAC=R*KAPPA/((L3/L2)-TWO*L1*KAPPA/L2+(ONE-R)*L1*KAPPA/L2)
      TANDC=TAND/R
      RE=KAPPAC
      TAM=TANDC-TANW*DDA/DA
      AIM=RE*TAM
      GO TO 15
  210 RE=RA+8368.D-4*(RA**2-RA)*(C2C(I)-D3(I))/C2C(I)
   18 TAM=AIM/RE-TANW*DDA*(4.2D-1+W/RA)/((4.2D-1+W)*DA)
      AIM=RE*TAM
   15 WRITE(6,300) SNC,DX,DC,FCC,B,RE,AIM,TAM,Z16
      SIGMA(I)=1.6669198D-2*AIM/DSQRT(LW02)
   10 CONTINUE
      WRITE(6,301)
      DO 11 I=1,NX
      WRITE(6,302) T(I),SIGMA(I),C2C(I)
   11 CONTINUE
      GO TO 77
   88 CALL EXIT
      END
```

In the latter part of this report period we have investigated the possibility of using derivatives in the shorted line (also corresponding relations in the open circuited line) calculations for finding a and b in the expression

$$\tanh (a + jb) / (a + jb) = C + jD$$

when C and D are known. In principle the use of derivatives to extrapolate to the solution could provide faster, more efficient programs than the blind stepping method we have used. In practice we found that the damping required (in a general use program) because of large changes in values of the derivatives resulted in little or no improvement.

If approximately correct initial values of a and b are obtained from charts (or in the case of thin samples at the quarter wave plane, from algebraic expressions) iteration using derivatives is useful, as in our programs for the HP9810A calculator. These are available on request.

DATA INDEX

Data Index (cont.)

DIELECTRIC PARAMETERS

Dielectric parameters in this series of reports have the variables in one of the following notations:

κ', $\varepsilon'/\varepsilon_0$, K, K1, dielectric constant relative to vacuum

κ'', $\varepsilon''/\varepsilon_0$, K2, dielectric loss factor relative to vacuum

tan δ, tan δ_d, TAN DELTA, D.F., dielectric loss tangent (dissipation-factor)

κ_m', μ'/μ_0, magnetic pearmeability relative to vacuum

κ_m'', μ''/μ_0, magnetic loss factor relative to vacuum

tan δ_m, magnetic loss tangent

σ, a.c. volume conductivity in mho/cm

ρ, a.c. volume resistivity in ohm-cm

MATERIALS INDEX

I. Inorganic Compounds

Aluminum nitrides — General Electric/RSD — Measurements made under AMMRC contract DAAG46-79-C-0096, reference AMMRC report AMMRC-TR81-45(March 1982)

CVD-AlN-3 24 GHz, E parallel to deposition plane

T^oC	κ	tan δ
30	7.47	.0020
96	7.56	.0019
205	7.68	.0026
300	7.83	.0122
401	7.98	.0225
518	8.21	.0606
589	8.36	.110
672	8.59	.181
723	8.74	.248
800	9.0	.35

Hot-pressed (HP-21) 2.64 gm/cc(81%)

T^oC	κ	tan δ
27.5	5.963	.00216
136	6.038	.00243
222	6.090	.00275
311	6.144	.00239
408	6.202	.00234
507	6.285	.00276
607	6.380	.00320
708	6.457	.00372
738	6.492	.00395
800	6.549	.00435

Aluminum oxide

Single crystal, sapphire — Unknown

E ⊥ to optic axis, 8.5 GHz

	κ	tan δ
Sample 1	9.42	.00006 ± .00004
2	9.38	<.00002

Ceramic, Wesgo 4078 — Western Gold & Pt.

8.5 GHz, 24^oC

κ	tan δ
9.31	.00034

Aluminum oxynitride crystal — AMMRC

T^oC	Freq., Hz	10^2	10^3	10^4	10^5	10^6	10^7
25	κ'	8.56	8.56	8.56	8.56	8.56	8.56
	tan δ	.0015	.0011	.0006	.0005	.0005	.0004
	σ	7.1E-13					
150	κ'	8.62	8.60	8.60	8.60	8.60	8.60
	tan δ	.0033	.0037	.0024	.0018	.0010	.0006
	σ	1.6E-12					
300	κ'	8.97	8.79	8.72	8.65	8.64	8.64
	tan δ	.0270	.0108	.0044	.0029	.0026	.0021
	σ	1.343E-11					
400	κ'	10.0	9.40	9.13	8.95	8.76	8.72
	tan δ	.0709	.0495	.0229	.0078	.0037	.0031
	σ	3.94E-11					
500	κ'	14.0	11.7	9.92	9.18	8.95	8.87
	tan δ	1.014	.212	.0941	.0370	.0136	.0070
	σ	7.89E-10	1.38E-9				

Beryllium oxide

Ceramics

418S — Ceradyne

23°C, 8.5 GHz
Density = 2.842 g/cm^3

κ' = 6.60; tan δ = .00030

K150 — Unknown

23°C, 8.5 GHz

Sample	Density (g/cm^3)	κ	tan δ
1	2.891	6.715	.00037
2	2.882	6.688	.00039

Boron nitride

Cubic, CVD Specimen No. 1025(3)
24°C, 24 GHz

κ' = 7.01; tan δ = .0048

General Electric/RSD measured under AMMRC Contract No. DAAG46-79-C-0047; reference AMMRC TR79-45(August, 1979)

Hot-pressed, 8.5 GHz, 24°C

Grade HP — Carborundum

Sample	Density (g/cm^3)	κ	tan δ
1	1.895	4.28	.00078
2	1.879	4.27	.00078

Grade HBC — Union Carbide

Sample	Density (g/cm^3)	κ	tan δ
1	1.943	4.10	.00015
2	1.944	4.08	.00013

Woven fiber

BN-3DX 59-1-1.74 — 14 GHz — Ford Aerospace

24°C

Face	Rotation,°	κ	tan δ
1	0	3.775	.00111
	90	3.683	.00047
2	0	3.706	.00066
	90	3.720	.00148

Face 1, rotation 0°

T°C	κ	tan δ
200	3.796	.00105
400	3.797	.00114
600	3.805	.00092
800	3.818	.00135

Cordierite ceramics

Brunswick 2, 8.5 GHz — Brunswick

		Against short		$\lambda/4$ away		
Sample	Face	κ	tan δ	κ	tan δ	Density (g/cm^3)
1	1	4.735	.00050			2.4472
	2	4.729	.00047			
2	1	4.730	.00050	4.69	.00047	2.5521
	2	4.722	.00047			
3	1	4.717	.00051			2.4372
	2	4.711	.00056			

Cordierite ceramics (cont.)

Brunswick 2 (1+2+3) stacked
Silver paint + silver foil

Resonant-cavity method TE114

T^oC	κ	tan δ
25	4.7237	.00050
81	4.7410	.00054
103	4.7484	.00054
133.5	4.7585	.00057
162	4.7664	.00058
200	4.781	.00066
232	4.7936	.00081
261	4.806	.00114
372	4.8464	.0023
409	4.8606	.0033
418	4.865	.0035
457	4.886	.0046
500	4.937	.0061

Brunswick 2-2

Standing-wave method

T^oC	κ	tan δ
23	4.729	.00052
100	4.7[illegible]4	.00054
200	4.790	.00062
300	4.829	.00137
400	4.863	.00283
500	4.890	.00570
600	4.935	.0115
700	4.980	.0228
900	5.09	.080

$$\frac{\Delta K/K}{\Delta T} \text{ at } 300^oC = \frac{4.8205-4.7237}{4.7237 \times 275} = 7.45E-5;$$

$$\frac{\Delta K/K}{\Delta T} \text{ at } 900^oC = 8.70E-5$$

Coor CD1 — Coors

Sample	Face	Against short κ	Against short tan δ	$\lambda/4$ away κ	$\lambda/4$ away tan δ	Density (g/cm^3)
1	1	4.858	.00133	4.857	.00122	2.4709
	2	4.859	.00129	4.856	.00120	
2	1	4.885	.00122	4.872	.00120	2.4816
	2	4.881	.00122	4.871	.00121	
3	1	4.894	.00134	4.884	.00121	2.4862
	2	4.894	.00124	4.883	.00120	

Coor CD1-1, silver paint + silver foil

Resonant-cavity method

T^oC	κ	tan δ
26.3	4.8593	.00130
88	4.8772	.00145
119	4.888	.00157
131	4.891	.00164
166.7	4.905	.0018
210.5	4.919	.00229
243	4.928	.00243
265	4.935	.0025
287	4.941	.0035
308	4.955	.0039
327	4.962	.0045
346	4.971	.0050
373	4.983	.0072

Standing-wave method

T^oC	κ	tan δ
23	4.857	.00130
100	4.881	.00146
200	4.913	.00200
300	4.943	.00307
400	4.975	.00538
500	5.009	.0111
600	5.046	.0189
700	5.092	.034
800	5.142	.060
900	5.202	.110

$$\frac{\Delta K/K}{\Delta T} \text{ at } 300^oC = \frac{.0917}{4.859 \times 273.7} = 6.89E-5;$$

$$\frac{\Delta K/K}{\Delta T} \text{ at } 900^oC = \frac{.345}{4.857 \times 877} = 8.10E-5$$

Cordierite ceramics (cont.)

"Rayceram" QNP 2102 — Raytheon

Resonant-cavity method

4.17 GHz (TE111 mode)

T^oC	κ	tan δ
20.5	4.7448	.0018
64	4.7600	.0019
104.5	4.7767	.0022
255.3	4.837	.0034
334	4.869	-
368	4.880	-

8.73 GHz (TE113 mode)

T^oC	κ	tan δ
20.5	4.7439	.00165
74.7	4.7633	.0019
100.5	4.7761	.0020
254	4.8335	.0034
295	4.8492	.0041
374	4.9018	.0052
414	4.9145	.0057

Standing-wave method

"Rayceram" QNP 2102 in room-temperature holder

	κ	
Pc. 1	4.734	.00154
Pc. 2	4.701	.00157
Pc. 3	4.714	.00155
Pcs. 1/2/3	4.736	.99157

At 8.515 GHz

T^oC	κ	tan δ
23	4.736	.00154
100	4.769	.0020
200	4.809	.0033
300	4.852	.0047
400	4.897	.0063
500	4.944	.0082
600	4.992	.0102
700	5.040	.0124
800	5.096	.0152

Cordierite + 10% TiO_2 — Raytheon

8.515 GHz, standing-wave method

T^oC		Face	κ	tan δ
24	RTH	1	6.277	.00144
24		2	6.272	.00143
28	HTH	2	6.252	.0015
100			6.252	.0017
200			6.280	.0026
300			6.292	.0041
400			6.314	.0058
500			6.353	.0077
600			6.391	.0101
700			6.425	.0134
800			6.443	.0153

Ferrites — Transtech

TT-1-105 — 2.45 GHz

T^oC	$\varepsilon'/\varepsilon_o$	tan δ	Conductivity (mho-cm)	μ'/μ_o	tan δ_m	Attenuation (db/cm)
25	12.8	.0008±.0005	1.4E-5	-.160	-10.03	13.6
50	12.8	.001	1.7E-5	-.141	- 8.60	11.4
75	12.8	.0012	2.E-5	-.081	-11.0	9.36
100	12.8	.0015	2.6E-5	.023	23.8	6.47
125	12.9	.0015	2.6E-5	.162	1.34	2.64
150	12.9	.0011	1.8E-5	.48	.035	.160
175	13.0	.0015	2.65E-5	.80	.0086	.0623
200	13.1	.0025	4.46E-5	1.053	.0062	.073
250	13.3	.0067	1.21E-4	1.036	.0072	.117
300	13.4	.0139	2.53E-4	1.031	.0080	.184
350	13.6	.0314	5.81E-4	1.019	.0094	.344
400	13.8	.070	1.31E-3	1.014	.0124	.707
500	14.1	.392	7.5E-3	1.00	.028	3.71
			1 GHz			
25	12.8	.0005±.0003	3.6E-6	2.097	2.097	7.7

"Ferrimag" 5 (BaO-$6F_2O_3$) — Permag

24°C, 14 GHz

$\kappa' = 20.\pm 5$, tan $\delta_d = .009 \pm 4$, $\mu'/\mu_o = 1.37 \pm .1$, tan $\delta_m = .024 \pm .01$

Germanium mullite — General Electric

24 GHz

T^oC	κ	tan δ	T^oC	κ	tan δ
25	6.92	.0003	450	7.54	.0071
77	7.00	.0002	540	7.67	.0128
100	7.03	.0003	606	7.76	.0152
180	7.16	.0011	674	7.85	.0180
300	7.33	.0031	734	7.93	.022
375	7.44	.0048	800	8.04	.026

Lithium Niobate — MIT Lincoln Lab.

24 GHz

	E ‖ Y	E ‖ X
κ	27.9	39.
tan δ	.0122	.0054

Magnesium fluoride, IRTRAN 1 — Eastman Kodak

8.5 GHz 23°C

$\kappa = 5.276$ tan $\delta = .00017$

Magnesium fluoride, IRTRAN 1 (cont.) Eastman

24 GHz

T^oC	κ	tan δ	T^oC	κ	tan δ
25.3	5.29	.0001	367	5.78	.0006
53	5.33	.0001	451	5.93	.0007
104	5.39	.0001	517	6.06	.0009
146	5.45	.0002	597	6.23	.0013
194	5.52	.00025	654	6.36	.0022
239	5.57	.00035	722	6.6	.060
293	5.66	.0005			

Sialons and Silicon nitride AFML (Ruh)

Si_3N_4 + 6% CeO_2 + 15% BN

1800°C vacuum hot-pressed, 20 Dec. 1977, density=2.866 g/cm^3

1900°C vacuum hot-pressed, Jan. 1978, density=2.848 g/cm^3

14 GHz

Face	Rotation (degrees)	T^oC	κ	tan δ	Face	Rotation (degrees)	T^oC	κ	tan δ
1	0	22	7.175	.00966	1	0	22	7.166	.0131
	90	22	7.157	.00931		90	22	7.131	.0138
2	0	22	7.159	.00935	2	0	22	7.144	.0133
	90	22	7.148	.00875		90	22	7.173	.0134
1	0	100	7.25	.0125	1	0	100	7.22	.0154
		200	7.35	.0180			200	7.32	.0210
		300	7.45	.0247			300	7.42	.0249
		400	7.58	.0357			400	7.53	.0415
		500	7.72	.0475			500	7.65	.0548
		600	7.88	.059			600	7.78	.070

G.E. 128-2 General Electric

Resonant-cavity measurements at approx. 8.5 GHz

T^oC	κ	tan δ
25	7.67	.0014
100	7.72	.0014
200	7.78	.0015
300	7.85	.0015
400	7.91	.0015
500	7.97	.0015
600	8.05	.0015
700	8.13	.0016
800	8.21	.0017
900	8.30	.0018
1000	8.40	.0021
1100	8.51	.0026
1150	8.57	.0030
1200	8.62	.0037
1220	8.65	.0040
1250	8.70	.0050
1270	8.75	.0098

Standing-wave measurements at 24 GHz

T^oC	κ	tan δ
25	7.65	.0028
100	7.67	.0022
200	7.69	.0024
300	7.73	.0025
400	7.78	.0026
500	7.84	.0027
600	7.89	.0027
700	7.95	.0026
800	8.02	.0025
25	7.76	.0019

Sialons and Silicon nitride (cont.)

G.E. 129-1 — General Electric

Resonant-cavity measurements at approx. 8.5 GHz

T^oC	κ	tan δ
25	7.79	.0015
100	7.815	.0016
200	7.86	.0017
300	7.91	.0017
400	7.97	.0018
500	8.03	.0019
600	8.09	.0020
700	8.16	.0021
800	8.22	.0022
900	8.30	.0023
1000	8.37	.0026
1100	8.46	.0030
1150	8.50	.0033
1200	8.57	.0038
1260	8.67	.014

Standing-wave measurements at 24 GHz

T^oC	κ	tan δ
25	7.67	.0016
100	7.68	.0022
200	7.70	.0028
300	7.73	.0031
400	7.77	.0031
500	7.82	.0032
600	7.87	.0033
700	7.94	.0035
800	8.01	.0040

G.E. 130-1

T^oC	κ	tan δ
25	7.44	.0014
100	7.48	.0014
200	7.53	.0015
300	7.58	.0015
400	7.62	.0016
500	7.66	.0017
600	7.71	.0018
700	7.75	.0019
800	7.81	.0020
900	7.87	.0022
1000	7.93	.0025
1100	8.02	.0040
1150	8.08	.0057
1200	8.18	.0100

T^oC	κ	tan δ
25	7.55	.00182
100	7.58	.00225
200	7.62	.00266
300	7.65	.00274
400	7.69	.00272
500	7.72	.00268
600	7.77	.00276
700	7.81	.00292
800	7.87	.0031

Silica

Corning 7940 (1979), 8.5 GHz — Corning

In room-temperature sample holder

Samples	κ	tan δ
1 pc.	3.825	.00012 $\pm$ .00003
2 pcs. stacked	3.816	.00010 $\pm$ .00002
3 pcs. "	3.815	.00010 $\pm$ .00003
4 pcs. "	3.820	.000122 $\pm$ .000012

Silica (cont.)

Corning 7940 (cont.) — Corning

Temperature run, 2 pcs. stacked

T^oC	κ	tan δ
22	3.815	.0001 + .0001 - .00005
104	3.819	
165	3.823	
222	3.829	
326	3.837	
410	3.843	
510	3.853	
611	3.862	
699	3.879	
751	3.882	

Temperature run, 3 pcs. stacked

T^oC	κ	tan δ
19.6	3.812*	.00014 ± .00005
100	3.816	.00012
207	3.822	.00010
300	3.829	.00011
422	3.829	.00010
488	3.847	.00011
572	3.847	.00011
656	3.862	.00011
722	3.879	.00010
750	3.882	.00013

*Not corrected for stacking error.

Temperature run, 4 pcs. stacked

T^oC	κ**	tan δ
25.3	3.822	.00014 ± .0003
100	3.827	.00011
200	3.835	.00010
297	3.844	.00010
400	3.855	.00010
493	3.866	.00012
600	3.878	.00013
725	3.894	.00014
760	3.900	.00014
800	3.905	.00014
25.0	3.823	.00014

Previous resonant-cavity data†

T^oC	κ	tan δ
25	3.823	.00015 ± .00007
100	3.829	.00014
200	3.836	.00012
300	3.845	.00012
400	3.855	.00012
500	3.866	.00012
600	3.878	.00012
700	3.890	.00012
800	3.904	.00013

**Corrected for stacking error.

† Corrected for thermal expansion and frequency shift from 4 to 8.5 GHz.

Slip cast with moisture proofing, 8.5 GHz — Harbison-Walker

T^oC	κ	tan δ
22	3.224	.00075
100	3.233	.00095
200	3.242	.00092
300	3.247	.00090
400	3.257	.00140
500	3.268	.00180

T^oC	κ	tan δ
600	3.281	.00250
700	3.293	.00335
800	3.304	.0042
900	3.317	.0050
22	3.198	.00054

Silica (cont.)

Slip cast, Brunswick 201B (1978), 8.5 GHz — Brunswick

T^oC	κ	tan δ	T^oC	κ	tan δ
22	3.460	.00104	650	3.481	.00042
100	3.471	.00080	700	3.480	.00049
200	3.475	.00050	750	3.479	.00058
300	3.475	.00035	800	3.482	.00068
400	3.474	.00028	900	3.490	.00090
500	3.477	.00030	171	3.456	.00016
600	3.481	.00037	57	3.450	.00024

Silica Composite ADL-4D6 (1.59gm/cc)

General Electric/RSD measured under AMMRC Contract No. DAAG46-79-C-0047; reference AMMRC TR79-45(August, 1979)

After preheat to 700°C

8.5 GHz, Mode 1			---continued			24 GHz As received		
T^oC	κ	tan δ	T^oC	κ	tan δ	T^oC	κ	tan δ
22	2.656	.00153	503	2.673	.00062	24	2.878	.0072
1 hour			587	2.684	.00092	117	2.878	.0055
22	2.660	.00218	735	2.703	.00120	217	2.856	.0039
67.5	2.658	.00202	790	2.709	.00132	271	2.841	.0023
83.5	2.657	.00185	835	2.714	.0016	320	2.833	.0016
116.6	2.655	.00093	973	2.726	.0028	404	2.823	.0018
123	2.654	.00083	1100	2.736	.0032	496	2.813	.0020
190	2.650	.00079	1178	2.741	.0036	546	2.809	.0021
252	2.649	.00061	1234	2.746	.0040	698	2.797	.0022
300	2.652	.00061	1290	2.77	.0045	750	2.793	.0023
411	2.663	.00120	1321	2.79	.0048	800	2.790	.0023
429	2.665	.00086	1400	2.82	.0057	95	2.822	.0020

8.5 GHz, Mode 2

T^oC	κ	tan δ	T^oC	κ	tan δ
22	2.8295	.00196	623	2.832	.00079
130	2.8284	.00122	731	2.835	.00126
189	2.826	.00086	1016	2.860	.00302

Silicates

Corning 9754 glass — Corning

8.515 GHz			24 GHz		
T^oC	κ	tan δ	T^oC	κ	tan δ
22	8.72	.0069	23	8.69	.0089
100	8.91	.0069		8.83	.0090
200	9.18	.0070		9.05	.0093
300	9.47	.0072		9.29	.0097
400	9.78	.0074		9.55	.0103
500	10.08	.0079		9.83	.0108
600	10.4	.0085		10.14	.0116

Silicates (cont.)

"Cervit" Glass-1, 8.515 GHz — Owens-Illinois

T°C	κ	tan δ	T°C	κ	tan δ
22	6.38	.050	400	8.52	.145
100	6.87	.066	444	8.88	.184
200	7.37	.081	538	9.12	.346
300	7.85	.097			

Silicon carbide — Vesuvius Crucible

Four-terminal measurements on samples of various conductivities

Sample designation	Resistivity in ohm-cm 100 Hz	1 kHz	10 kHz
NR2	.661	.660	.658
NH1	.06414	.06385	.06377
LR1	.004593	.004592	.004509
LH1	.003604	.003598	.003587

Silicon carbide + glass matrix — ITT Gilfillan

May stone .25, 2.45 GHz

T°C	κ	tan δ	T°C	κ	tan δ
25	25.6	.247	300	29.5	.0983
100	26.2	.275	400	29.7	.108
150	27.2	.239	450	29.6	.109
200	28.7	.115	500	29.4	.127
250	29.4	.0956			

<u>Repeat run</u>

T°C	κ	tan δ	T°C	κ	tan δ
25	25.6	.190	250	29.3	.0955
100	26.2	.154	300	29.7	.0984
200	28.7	.101	400	29.8	.107

Silicon nitride — Samples from AMMRC

sintered, 8.515 GHz

Sample	Face	Rotation (degrees)	T°C	κ	tan δ
HP-X-214	1	0	25	8.653	.00744
		90		8.646	.00735
	2	0		8.586	.00655
		90		8.590	.00654
7-24	1	0		7.787	.0229
		90		7.742	.0214
	2	0		7.455	.0226
		90		7.511	.0262
8-3A	1	0		7.840	.467
		90		7.828	.440

Silicon nitride (cont.)

Hot-pressed, sample HP-X-214, 8.515 GHz — AMMRC

T^oC	κ	tan δ	T^oC	κ	tan δ
23.5	8.63	.0064	493	9.17	.0067
100	8.70	.0066	596	9.30	.0065
207	8.81	.0065	679	9.40	.0064
290	8.92	.0065	700	9.44	.0066
395	9.06	.0070	752	9.50	.0067

Ceralloy 147Y-1, 24 GHz — Ceradyne

Measurements in room-temperature sample holder

Sample	Face	Rotation (degrees)	κ	tan δ
A	1	0	8.79	.00363
	2	0	8.73	.00894
	2	45	8.83	.00354
	2	135	8.72	.00746
B	1	0	8.26	.00166
	1	45	8.27	.00452
	1	135	8.42	.00385
	2	0	8.25	.0015
	2	90	8.39	.0093

Temperature runs

A, Face 1, 0^o			B, Face 1, 0^o		
T^oC	κ	tan δ	T^oC	κ	tan δ
25	8.79	.0036	25	8.26	.0016
100	8.84	.0041	100	8.30	.0017
200	8.90	.0047	200	8.38	.0019
300	8.97	.0056	300	8.47	.0023
400	9.05	.0061	400	8.56	.0024
500	9.14	.0063	500	8.66	.0023
600	9.23	.0061	600	8.77	.0031
700	9.33	.0062	700	8.88	.0048
750	9.38	.0075	750	8.93	.0057
800	9.44	.0091	800	8.99	.0067

Silicon nitride

Chemical vapor deposition, specimen No. 231 General Electric/RSD
Measured at 24GHz under AMMRC Contract No. DAAG46-79-C-0096; reference AMMRC TR-81-45(March 1982) 24 GHz

T^oC	κ	tan δ	T^oC	κ	tan δ
28.5	8.07	.0003	495	8.64	.0004
99	8.13	<.0003	460	8.73	.0004
208	8.24		624	8.82	.0004
294	8.34		650	8.87	.0004
358	8.44		696	8.95	.0005
414	8.53	<.0004	733	6.01	.0005

Silicon nitride plus BN fibers AVCO

Sample 1 at room temperature

Against short κ' = 9.40; tan δ = .118

$\lambda/4$ away κ' = 9.00; tan δ = .144

Temperature run, average

T^oC	κ	tan δ	T^oC	κ	tan δ
25	9.15	.131	500	9.33	.137
100	9.18	.132	600	9.38	.137
200	9.21	.135	700	9.53	.138
300	9.25	.136	800	9.47	.139
400	9.30	.137			

Sample 2 at room temperature

Against short κ' = 9.25; tan δ = .125

$\lambda/4$ away κ' = 8.69; tan δ = .144

Calculated as a magnetic sample:

κ' = 8.04; tan δ_d = .9215; μ'/μ_o = 1.12; tan δ_m = .121

Silicon mullite, ceramic General Electric

8.5 GHz, density = 3.15 g/cm^3			24 GHz, 3.12 g/cm^3		
T^oC	κ	tan δ	T^oC	κ	tan δ
23	7.02	.0004	23.5	6.98	.0002 $\pm$ .0001
83	7.09	.0005	111	7.04	.0003
207	7.21	.0008	2.3	7.14	.0004
357	7.40	.0023	276	7.22	.0012
440	7.55	.0043	374	7.34	.0032
534	7.60	.0062	460	7.46	.0070
573	7.75	.0067	554	7.59	.0138
632	7.84	.0072	607	7.66	.0177
698	7.95	.0073	660	7.73	.023
740	8.01	.0073	719	7.82	.030
800	8.12	.0072	740	7.86	.033

Sulfur Merck Chemical

8.5 GHz

	T^oC	Density (g/cm^3)	κ	tan δ
Pressed pellet	23	1.683	3.28	.00005±.00001
Fast cooled from liquid	23	1.976	3.78	.00005±.00001
Pressed pellet (m.p. 120°C)	23		3.379	.000046
	48		3.378	.000062
	65		3.378	.000052
	88		3.379	.000008
	101		3.375	.00012
	126.7		3.289	.00038
Liquid (b.p. 447°C)	125		3.38	.0004
	140		3.38	.0007
	160		3.38	.0005
	180		3.39	.0006
	200		3.40	.0006
	220		3.40	.0007
	240		3.40	<.002
	260		3.41	
	280		3.41	
	300		3.38	<.004
	320		3.33	
	340		3.28	
	360		3.24	
	380		3.20	
	400		3.17	
	444		3.14	<.005

Zinc sulfide Eastman Kodak

(IRTRAN 2), 8.5 GHz, 24°C, density = 4.081 g/cm^3

κ' = 8.43; tan δ = .00160

24 GHz

T^oC	κ	tan δ	T^oC	κ	tan δ
25	8.32	.00170	600	9.32	.0069
100	8.44	.00172	650	9.56	.0148
200	8.61	.00175	700	9.75	.0244
300	8.79	.0019	730	9.92	.033
400	9.00	.0025	750	10.03	.037
500	9.24	.0029			

Zirconia fiber products Zircoa

24 GHz, 24°C

	κ	tan δ
"ZIRCAR" Type ZYW-30A	2.63	.0082
"ZIRCAR" Type ZYF-100	1.474	.0014

II. Miscellaneous Inorganics

"Pyroceram"9606 — Corning

Measurements on a group of 12 samples received in December 1977 from General Dynamics and one sample from Raytheon

Standing-wave measurements at 8.515 GHz, 24°C

Sample No.	Face 1 Diameter (inches)	Face 1 κ	Face 1 tan δ	Face 2 Diameter (inches)	Face 2 κ	Face 2 tan δ	Density (g/cm³)
1 BH	.9993	5.5426	.00023	.9996	5.5418	.00022	
1 OP		5.5457	.00020		5.5436	.00022	
2 BH	1.0005	5.5382	.00018	1.0007	5.5389	.00018	
3	1.0004	5.5430	.00020	1.0003	5.5431	.00019	
4	.9992	5.5395	.00021	.9994	5.5405	.00021	
5	.9998	5.5456	.00020	.9998	5.5465	.00020	
6.	.9993	5.5481	.00022	.9993	5.5457	.00020	2.5933
7	.9996	5.5396	.00021	.9997	5.5414	.00022	
8	1.0000	5.5421	.00021	1.0003	5.5415	.00021	2.5914
9	.9998	5.5446	.00021	1.0000	5.5442	.00021	2.5929
10	1.0003	5.5428	.00021	1.0005	5.5448	.00021	2.5927
11	.9987	5.5359	.00023	.9992	5.5362	.00022	2.5898
12	.9997	5.5469	.00021	.9997	5.5461	.00020	2.5922

BH - Sample measured against bottom of sample holder.

OP - Sample measured a quarter wavelength from end using a polystyrene tube spacer.

Resonant-cavity measurements at approx. 8.5 GHz

T°F	#1 κ	#1 tan δ	T°F	#2 κ	#2 tan δ	#3 κ	#3 tan δ	T°F	#4 κ	#4 tan δ
67	5.542	.00023	69	5.539	.00020	5.543	.00020	74	5.540	.00021
300	5.586	.0003	300	5.581	.00029	5.585	.00030	300	5.584	.0004
600	5.643	.0007	600	5.635	.0008	5.639	.0008	600	5.636	.0010
900	5.714	.0021	900	5.701	.0014	5.712	.0016	900	5.713	.0018
1200	5.80	.0052	1200	5.784	.0045	5.79	.0045	1200	5.785	.0054

T°F	#5 κ	#5 tan δ	T°F	#7 κ	#7 tan δ	#8 κ	#8 tan δ	T°F	#9 κ	#9 tan δ
72	5.546	.0002	72	5.541	.0002	5.542	.0002	72	5.544	.0002
300	5.588	.0004	300	5.586	.0003	5.584	.0004	300	5.589	.0004
600	5.646	.0010	600	5.647	.0006	5.643	.00115	600	5.649	.0012
900	5.710	.0015	900	5.709	.0014	5.710	.0023	900	5.713	.0028
1200	5.793	.0045	1200	5.781	.0052	5.790	.0043	1200	5.786	.0056

"Pyroceram"9606 (cont.)

Resonant-cavity measurements at approx. 8.5 GHz (cont.)

#10			#12		
T^oF	κ	tan δ	T^oF	κ	tan δ
72	5.544	.0002	70	5.546	.0002
300	5.589	.0004	300	5.589	.0004
600	5.649	.0008	600	5.646	.0010
900	5.715	.0018	900	5.714	.0021
1200	5.792	.0059	1200	5.798	.0058

	#11		#6		Raytheon	
T^oF	κ	tan δ	κ	tan δ	κ	tan δ
74	5.536	.00022 ± 5	5.547	.00022 ± 5	5.661	.0003 ± 1
300	5.581	.00028 ± 5	5.587	.00030 ± 5	5.697	.0005 ± 1
600	5.643	.0007 ± 2	5.642	.00053 ± 7	5.751	.0010 ± 2
900	5.718	.0018 ± 4	5.708	.0014 ± 2	5.808*	.0019* ± 4
1200	5.81	.0041 ± 5	5.79	.0042 ± 4		

Error in right digit shown for tan δ

Error in κ ± .002 except at 1200°F ± .03

*Extrapolated from run to 752°F

Average values for 12 samples from Gen. Dynamics

Dec. 1977, densities: 2.5898 to 2.5933 gm/cm^3

8.5 GHz

T°F	T°C	K	D.F.
73	23	5.542	.00021
300	149	5.586	.0003
600	316	5.643	.0009
900	482	5.711	.0018
1200	649	5.79	.0049

From Raytheon Nov. 1979:

8.5 GHz

T°F	T°C	K	D.F.
73	22.6	5.619	.00028
212	100	5.649	.00033
392	200	5.683	.00060
572	300	5.720	.00105
752	400	5.760	.00165
932	500	5.804	.00263
1112	600	5.847	.00388
1292	700	5.888	.00567
1400	760	5.915	.0070
1472	800	5.932	.0082

"Pyroceram" 9606, continued

From Gen. Dynamics July 1978:

8.5 GHz

T°C	K	D.F.
22.3	5.419	.00030
100	5.453	.00047
200	5.501	.00069
299	5.549	.00097
400	5.601	.00139
500	5.661	.00197
600	5.725	.00294
700	5.781	.00469
750	5.814	.00569
810	5.864	.00734

"Pyroceram" 9600 Corning

Sample from Gen. Dynamics July 1978

8.5 GHz

T°F	T°C	K	D.F.
73	23	6.268	.00024
122	50	6.259	.00022
176	80	6.254	.00022
212	100	6.257	.00024
248	120	6.262	.00026
284	140	6.270	.00029
338	170	6.282	.00033
392	200	6.296	.00042
572	300	6.334	.00050
752	400	6.377	.00098
932	500	6.424	.00236
1112	600	6.477	.0044
1292	700	6.542	.0074
1472	800	6.615	.0113
1517	825	6.638	.0124

Pyroceram 960Q Sample from General Dynamics 1980

8.515 GHz			24 GHz		
T^oC	κ	tan δ	T^oC	κ	tan δ
25	6.228	.00027	21	6.173	.00032
100	6.209	.00025		6.157	.0004
200	6.206	.00041		6.164	.0005
300	6.215	.00070		6.179	.0006
400	6.236	.00140		6.198	.0010
500	6.265	.00295		6.227	.0020
600	6.296	.0060		6.275	.0050
700	6.321	.0112		6.338	.013
800	6.35	.018		6.40	.020

"Pyroceram" 960Z

Sample from Gen. Dynamics July 1978

8.5 GHz

T°C	K	D.F
23.1	5.732	.00026
90	5.771	.00038
150	5.811	.00053
231	5.861	.00074
297	5.901	.00095
350	5.938	.00118
435	5.999	.00169
525	6.064	.00278
585	6.107	.00370
653	6.164	.00550
690	6.188	.00655
730	6.218	.00805
765	6.242	.00966
800	6.272	.0115

Corning

Samples from Gen. Dynamics 1980

	8.5 GHz		24 GHz	
T°C	K	D.F.	K	D.F.
21	5.688	.00024	5.663	.00062
100	5.737	.00052	5.695	.0005
200	5.795	.00097	5.743	.0008
300	5.853	.00208	5.790	.0012
400	5.919	.00305	5.843	.0017
500	5.987	.0054	5.900	.0028
600	6.054	.0105	5.960	.0048
700	6.132	.0162	6.030	.0076
800	6.19	.034	6.11	.012

Pipe Insulating Compound, fresh mix

Lebanon Steel Foundry

2.[illegible]9 GHz

T°F	K	D.F.
77	14.3	.15
100	14.3	.18
150	14.0	.22
200	13.6	.24
water lost, unstable		
300	2.8	.026
350	1.21	.0074
400	1.21	.0079

T°F	K	D.F.
500	1.22	.0096
600	1.23	.012
700	1.24	.016
800	1.26	.021
900	1.28	.028
1000	1.30	.040
1100	1.33	.056
1200	1.38	.081

COomposition:

Perlite	82 grams
SSF	5 grams
Water	23 ml
Silicate	87 grams
ZnO	13 grams

Chimney Flue Liner

Sample from MIT,Melcher

D.C. conductivity (one-minute) versus temperature

T°C	Sigma, mho/cm	T°C	Sigma, mho/cm	T°C	Sigma, mho/cm
22.5	4.40E-13	217.5	2.45E-10	583	5.53E-6
33	3.94E-14	232.6	4.88E-10	653	1.19E-5
55	1.33E-13	281	2.64E-9	704	1.88E-5
85	5.44E-13	302.5	5.11E-9	751	2.95E-5
103.5	1.22E-12	411	1.21E-7	793	4.37E-5
137	5.19E-12	495	5.44E-7	841	6.83E-5
161	1.53E-11	12hrs at 245°C		907	1.24E-4
192	7.42E-11	439	2.08E-7	969	1.90E-4
199	1.13E-10	576	5.04E-6	982	2.05E-4

CHIMNEY FLUE LINER

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3824	22.5	100.	5.254	0.793128	0.150943	0.44063E-10
3.3824	22.5	1000.	5.013	0.190604	0.038022	0.10589E-09
3.3824	22.5	10000.	4.902	0.076039	0.015511	0.42244E-09
3.3824	22.5	100000.	4.728	0.048433	0.010244	0.26907E-08
3.3824	22.5	1000000.	4.677	0.038693	0.008273	0.21496E-07
3.3824	22.5	9500000.	4.586	0.037590	0.008196	0.19839E-06
2.6799	100.0	100.	5.831	0.634580	0.108831	0.35254E-10
2.6799	100.0	1000.	5.316	0.336510	0.063298	0.18695E-09
2.6799	100.0	10000.	5.041	0.157745	0.031295	0.87636E-09
2.6799	100.0	100000.	4.892	0.093367	0.019087	0.51870E-08
2.6799	100.0	1000000.	4.767	0.067494	0.014160	0.37497E-07
2.6799	100.0	9500000.	4.703	0.054057	0.011495	0.28530E-06
2.1135	200.0	100.	11.029	8.651924	0.784484	0.48066E-09
2.1135	200.0	1000.	7.353	2.188744	0.297670	0.12160E-08
2.1135	200.0	10000.	5.963	0.751230	0.125976	0.41735E-08
2.1135	200.0	100000.	5.377	0.330298	0.061433	0.18350E-07
2.1135	200.0	1000000.	5.041	0.176863	0.035083	0.98257E-07
2.1135	200.0	9500000.	4.872	0.105227	0.021619	0.55589E-06
1.7447	300.0	100.	45.871	216.696243	4.724037	0.12039E-07
1.7447	300.0	1000.	18.303	30.440948	1.663164	0.16912E-07
1.7447	300.0	10000.	9.921	5.454198	0.549772	0.30301E-07
1.7447	300.0	100000.	6.811	1.675701	0.246042	0.93094E-07
1.7447	300.0	1000000.	5.654	0.607396	0.107423	0.33744E-06
1.7447	300.0	9500000.	5.025	0.275409	0.054803	0.14535E-05
1.4856	400.0	100.	203.086	3021.52686	14.878033	0.16786E-06
1.4856	400.0	1000.	55.502	314.027588	5.657909	0.17446E-06
1.4856	400.0	10000.	20.490	39.550461	1.930255	0.21972E-06
1.4856	400.0	100000.	10.048	7.160682	0.712662	0.39782E-06
1.4856	400.0	1000000.	6.826	1.731097	0.253602	0.96172E-06
1.4856	400.0	9500000.	5.554	0.569652	0.102563	0.30065E-05
1.2934	500.0	1000.	146.175	1804.77759	12.346718	0.10027E-05
1.2934	500.0	10000.	45.371	232.481750	5.124066	0.12916E-05
1.2934	500.0	100000.	18.036	33.052612	1.832572	0.18363E-05
1.2934	500.0	1000000.	9.184	6.321146	0.688289	0.35117E-05
1.2934	500.0	9500000.	6.103	1.639059	0.268581	0.86506E-05

8.5GHz 24°C as received, K=4.95, D.F.=.026; dry, K=4.81, D.F.=.012

New Jersey Sand #2, initial H_2O 4.25% M.I.T.,Melcher

Sigma, d.c. conductivity mho/cm

T°C	Sigma	T°C	Sigma	T°C	Sigma
28	2.11E-10	48 hours drying		475	2.02E-9
50	3.93E-10	63	2.09E-13	490	4.18E-9
79	1.01E-11	143	1.02E-13	549	2.20E-8
95	4.73E-12	229	7.99E-13	609	1.14E-7
127	6.97E-13	269	2.61E-12	705	8.65E-7
146	7.21E-13	328	1.84E-11	747	2.73E-6
216	1.11E-12	395	1.25E-10	831	4.56E-6
270	5.28E-12				

III. Organics

"Laminac" 4123 — American Cyanamid

25°C	Freq., MHz	κ'	tan δ
	10	3.71	.0167
	30	3.64	.0166

IL-T001 Absorber — TDK Industries

Sample from Army Materials and Mechanics Research Center (AMMRC)

Frequency, GHz	1	1.685	2.45	3	5	8.5
κ'	47.	43.	41.2	39.	36.	35.
tan δ	.104	.091	.102	.1445	.125	.085
μ'/μ_o	4.03	2.84	2.11	1.785	1.064	.85
tan δ_m	.687	.937	1.20	1.218	1.585	1.29
α, att. db/cm	9.56	16.28	24.5	28.2	41.5	51.6

Ferrite-Epoxy Resin Mixtures — AMMRC

FP-4 50 wt% ferrite

GHz	1	1.685	2.45	3	5	8.5	14	24
κ	4.469	4.328	4.178	3.153	4.119	3.950	3.92	3.90
tan δ	.0947	.0883	.0874	.0825	.0819	.0620	.0512	.046
μ'/μ_o	1.294	1.219	1.160	1.121	.979	.963	.989	1.00
tan δ_m	.0669	.1703	.1858	.1984	.190	.0528	.0163	.005

MAG-20 50 wt% 20 mesh magnetite

κ'	25.7	25.4	24.2	23.6	23.1	13.1	17.2	23.9
tan δ	.111	.109	.116	.114	.101	.0475	.03	.03
μ'/μ_o	1.75	1.57	1.44	1.37	1.12	.937	.897	1.03
tan δ_m	.276	.325	.378	.423	.515	.579	.49	.30

MAG-65 50 wt% 65 mesh magnetite

κ'	16.84	16.5	16.46	16.3	16.25	16.16	18.8*
tan δ	.0624	.0633	.0624	.0656	.075	.091	.0593*
μ'/μ_o	1.765	1.611	1.495	1.453	1.242	.985	2.149*
tan δ_m	.203	.254	.309	.326	.36	.419	.0979*

*freq. = 300 MHz

"Nylon" 66 — E. I. Dupont de Nemours and Co.

As Received, .559% water

Time, sec.	Freq., Hz	σ mho/cm
	1000	4.96E-11
	100	3.84E-12
60	.00265	6.95E-15
300	.0053	4.15E-15
778	.00020	2.59E-15
2400	.000066	1.66E-15

After vacuum drying, 2 days, 68°C

Time, sec.	Freq., Hz	σ mho/cm
	1000	2.61E-11
	100	2.14E-12
	20	3.17E-13
60	.00265	7.31E-17
120	.00133	5.41E-17
180	.00088	3.90E-17
300	.00053	2.98E-17

Frequencies less than 20 Hz calculated as $1/(2\pi t)$; this assumes charging current is negligible at these times.

"Nylon" 66

E. I. Dupont de Nemours and Co.
Sample molded by AMP

Water Content = .13%

T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
25.0	10.	3.662	0.017556	0.004794	0.97532E-13
25.0	20.	3.647	0.019707	0.005404	0.21896E-12
25.0	30.	3.642	0.021817	0.005990	0.36362E-12
25.0	50.	3.633	0.023715	0.006528	0.65876E-12
25.0	100.	3.618	0.027065	0.007480	0.15036E-11
25.0	200.	3.575	0.038884	0.010875	0.43204E-11
25.0	300.	3.566	0.042309	0.011863	0.70515E-11
25.0	500.	3.563	0.048911	0.013727	0.13586E-10
25.0	1000.	3.546	0.053687	0.015141	0.29826E-10
25.0	2000.	3.514	0.064390	0.018323	0.71545E-10
25.0	3000.	3.483	0.067870	0.019484	0.11312E-09
25.0	5000.	3.443	0.073324	0.021296	0.20368E-09
25.0	10000.	3.403	0.076979	0.022619	0.42766E-09
25.0	20000.	3.388	0.078724	0.023238	0.87472E-09
25.0	50000.	3.370	0.075890	0.022521	0.21081E-08
25.0	100000.	3.338	0.073176	0.021923	0.40653E-08
25.0	200000.	3.305	0.069027	0.020888	0.76697E-08
25.0	300000.	3.295	0.067828	0.020585	0.11305E-07
25.0	500000.	3.272	0.067459	0.020620	0.18739E-07
25.0	1000000.	3.247	0.063208	0.019468	0.35115E-07
25.0	2000000.	3.218	0.065476	0.020345	0.72752E-07
25.0	3500000.	3.200	0.067161	0.020990	0.13059E-06
25.0	6000000.	3.181	0.066853	0.021019	0.22284E-06
25.0	9500000.	3.154	0.066478	0.021075	0.35086E-06
25.0	30000000.	3.145	0.067829	0.021566	0.11305E-05

Water Content = .23%

T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
25.0	5.	4.413	0.108300	0.024539	0.30083E-12
25.0	10.	4.364	0.102985	0.023598	0.57214E-12
25.0	20.	4.316	0.098521	0.02[illegible]6	0.10947E-1[illegible]
25.0	30.	4.285	0.098263	0.022932	0.16377E-11
25.0	50.	4.229	0.098553	0.023304	0.27376E-11
25.0	100.	4.208	0.101789	0.024190	0.56549E-11
25.0	200.	4.119	0.123972	0.030094	0.13775E-10
25.0	300.	4.117	0.127763	0.031036	0.21294E-10
25.0	500.	4.067	0.135662	0.033354	0.37684E-10
25.0	1000.	4.014	0.143965	0.035868	0.79981E-10
25.0	2000.	3.957	0.148788	0.037600	0.16532E-09
25.0	3000.	3.918	0.154694	0.039479	0.25782E-09
25.0	5000.	3.868	0.155900	0.040306	0.43306E-09
25.0	10000.	3.795	0.160411	0.042272	0.89117E-09
25.0	20000.	3.724	0.158407	0.042539	0.17601E-08
25.0	50000.	3.635	0.151328	0.041632	0.42035E-08
25.0	100000.	3.574	0.141872	0.039696	0.78818E-08
25.0	200000.	3.507	0.128033	0.0365[illegible]0	0.14226E-07
25.0	300000.	3.477	0.121737	0.035016	0.20290E-07
25.0	500000.	3.450	0.113173	0.032808	0.31437E-07
25.0	1000000.	3.378	0.103135	0.030535	0.57297E-07
25.0	2000000.	3.358	0.091325	0.027190	0.10147E-06
25.0	3000000.	3.324	0.085876	0.025836	0.16698E-06
25.0	6000000.	3.297	0.083500	0.025323	0.27833E-06
25.0	9500000.	3.275	0.078812	0.024063	0.41595E-06
25.0	30000000.	3.259	0.072724	0.022316	0.12121E-05

AL-300, polyimide laminate — Atlantic Laminates

8.5 GHz

T°C	K	D.F	T°C	K	D.F.
26	4.65	.0192	179	4.64	.0238
48	4.71	.0203	212	4.64	.0238
71	4.69	.0212	237	4.57	.0220
96	4.70	.0230	259	4.58	.0229
123	4.72	.0235	279	4.58	.0229
148	4.65	.0228	26	4.39	.0103

"Avcoat" 8029 — AVCO

8.5 GHz

Thickness (cm)	T°C	K	D.F.	Thickness (cm)	T°C	K	D.F.
3.189	25	2.267	.00079	3.228	25		
3.202	60.5	2.257	.00079	reheated			
3.210	108	2.244	.00101	3.469	348	2.019	.0022
3.215	136	2.234	.00116	3.949	406	1.896	.00235
3.241	189	2.214	.00130	4.197	450	1.805	.00218
3.276	224	2.198	.00148	4.415	485	1.756	.00200
3.377	278	2.160	.00172	5.037	509	1.44	.0027
3.432	300	2.142	.00188	liquid with bubbles			
3.771	343	2.055	.0021				

AVCO K96 sample one — AVCO

8.5 GHz

T°C	E perpendicular to hot pressing dir. κ	tan δ	Thickness (cm)	E parallel to hot pressing dir. κ	tan δ
20.3	2.464	.00207	1.9350	2.383	.00160
64.3	2.453	.00203	1.9424	2.375	.00187
101	2.441	.00[illegible]10	1.9504	2.362	.00173
148	2.432	.00212	1.9559	2.351	.00165
203	2.406	.00221	1.9711	2.326	.00091
250	2.347	.00239	2.0239	2.265	.00115
303	2.056	.00250	2.3077	1.980	.00133
347			~ 2.56		

sample two, E perpendicular to hot pressing direction

T°C	κ	tan δ	Thick,cm	T°C	κ	tan δ	Thick.cm
20.2	2.448	.00150	2.2110	288	2.368	.00143	2.3187
57	2.443	.00136	2.2200	325	2.345	.00145	2.3522
84	2.436	.00140	2.2295	350	2.033	.00133	2.8405
101	2.431	.00132	2.2356	380	1.951	.00204	2.9830
130	2.424	.00130	2.2452	400	1.431	.00201	3.3168
148	2.418	.00127	2.2533	431	1.879	.00190	3.3124
188	2.399	.00100	2.2682	474	1.843	.00208	3.4829
208	2.390	.00112	2.2797	509	1.645	.00273	3.7028
248	2.385	.00136	2.2909				

Dielectric insulation boards — Cincinnati Milacron

23°C

Sample designation	Freq., Hz	1 M	10 M	100 M	300 M	1 G	3 G	8.5 G	14 G	24 G
PC-75	κ	4.14	3.94	3.68	3.64	3.61	3.59	3.568 ± .02	3.556	3.54
	tan δ	.0272	.0358	.0378	.0370	.0324	.0289	.0245	.0250	.026
65M62	κ	4.40	4.22	3.96	3.89	3.81	3.755	3.715 ± .01	3.700	3.685
	tan δ	.0305	.0377	.0415	.0394	.0358	.0304	.0256	.0269	.029
NP424	κ	4.49	4.22	3.95	3.89	3.82	3.76	3.710 ± .2	3.698	3.68
	tan δ	.0399	.044	.0455	.0449	.0394	.0337	.0300	.0312	.040
FR-4*	κ	4.58	4.46	4.33	4.53	4.48	4.46	4.445 ± .02	4.42	4.38
	tan δ	.0200	.0202	.0187	.0155	.0146	.0143	.0146	.0150	.016
MILCLAD CA7FR	κ	4.11	4.02	3.94	3.93	3.92	3.92	3.914 ± .01	3.912	3.90
	tan δ	.0118	.0130	.0132	.0127	.0115	.0105	.0099	.00985	.011
CIMCLAD MA*	κ	3.86	3.78	3.69	3.76	3.71	3.675	3.645 ± .01	3.635	3.625
	tan δ	.0126	.0114	.0110	.0109	.0105	.00928	.00888	.0095	.0105
CIMCLAD MA7FR	κ	4.17	4.09	3.99	3.98	3.96	3.94	3.929 ± .02	3.917	3.91
	tan δ	.0113	.0131	.0133	.0126	.0116	.0110	.0106	.0105	.0108
CIMCLAD ACAFR	κ	4.10	4.01	3.92	3.89	3.86	3.85	3.839 ± .006	3.83	3.82
	tan δ	.0122	.0135	.0142	.0137	.0114	.0104	.00995	.0103	.0109

1, 10, 100 M E ⊥ sheet; higher frequencies, E ∥.

*These are not isotropic within 1% in κ.

"Ethofoam" .0381 gm/cm^3 — Dart Industries, Sample from Sperry

Freq., GHz	K	D.F.
3	1.042	<.0001
8.5	1.042	.00001 ± .00001

"Rulon" II — Dixon Industries

24°C, Freq. run

Freq., Hz	DC, 1 minute	60	100	1 K	10 K	100 K	1 M	10 M	1 G	2.45 G	3 G
κ'		3.00	3.00	2.99	2.99	2.98	2.98	2.97	2.863	2.850	2.840
κ"		.0103	.0103	.00703	.00526	.00462	.00343	.00285	.00472	.00485	.00517
tan δ		.00344	.00342	.00235	.00176	.00135	.00115	.00096	.00165	.00170	.00182
σ mho/cm	1.5E-16	3.44E-13	5.7E-13	3.90E-12	2.92E-11	2.57E-10	1.90E-9	1.58E-8	2.62E-6	6.6E-6	8.61E-6
ρ ohm/cm	6.6E-15										

Temperature run

Freq., GHz	1.				2.45				3.			
T°C	κ'	κ"	tan δ	10^{6}x σ	κ'	κ"	tan δ	10^{6}x σ	κ'	κ"	tan δ	10^{6}x σ
26	2.863	.00472	.00165	2.62	2.850	.00485	.00170	6.60	2.840	.00517	.00182	8.61
74	2.858	.00503	.00176	2.79	2.839	.00520	.00183	7.07	2.832	.00586	.00207	9.77
109	2.854	.00605	.00212	3.36	2.835	.00641	.00226	8.72	2.827	.00732	.00259	12.2
136	2.852	.00915	.00321	5.9	2.833	.00904	.00319	12.3	2.824	.0105	.00372	17.5
173	2.851	.0151	.00531	8.41	2.829	.0151	.00533	20.5	2.819	.0164	.00583	27.4
205	2.855	.0225	.00787	12.5	2.827	.0216	.00765	29.4	2.817	.0228	.00811	38.1
250	2.868	.0280	.00975	15.5	2.829	.0274	.00969	37.3	2.819	.0290	.0103	48.6
22	2.844	.00435	.00153	2.42	2.838	.00400	.00141	5.45				

"Kevlar" laminates — E. I. Dupont de Nemours and Co., Samples from Sperry

8.5 GHz 22°C

After 21-1/2 days 95% R.H.

			κ	tan δ	wt. %
#1	Face 1	0	4.16	.113	4.084
#2	Face 1	0	3.93	.0772	3.230
#3	Face 1	0	4.19	.103	4.010
#4	Face 1	0	3.78	.0799	3.485

"Kevlar" laminates, continued As Received

Sample		Rotation (degrees)	Against short κ	Against short tan δ	%H_2O	Over $\lambda/4$ κ	Over $\lambda/4$ tan δ
#1	Face 1	0	4.24	.0534	3.505	4.098	.0707
		90	4.08	.0756		4.176	.0736
	Face 2	0	4.05	.084			
		90	4.11	.0819			
#2	Face 1	0	3.65	.0369	2.613		
		90	3.72	.0357			
#3	Face 1	0	4.17	.0886	3.677		
		90	4.24	.0895			
#4	Face 1	0	3.59	.0478	2.784		
		90	3.72	.0451			

Dried 2-1/2 days 80°C vac. oven

Sample	Rotation (degrees)	κ	tan δ
#1	0	3.35	.0092
	90	3.38	.0083
#2	0	3.37	.0109
	90	3.44	.0089
#3	0	3.43	.0110
	90	3.47	.0099
#4	0	3.20	.0103
	90	3.29	.0087

45 hours 95% R.H. Desiccator

Sample	Rotation (degrees)	κ	tan δ	%H_2O
#1	0	3.84	.0661	3.039
	90	3.92	.0672	
#2	0	3.62	.0318	2.019
	90	3.70	.0311	
#3	0	3.79	.0500	2.575
	90	3.84	.0503	
#4	0	3.60	.0465	2.637
	90	3.73	.0448	

Intermediate desiccation

for Sample #3

Hours	Rotation (degrees)	κ	tan δ	wt. %
69	0	3.88	.0583	2.931
	90	3.93	.0585	
100				3.228
139				3.465

FR is frequency in Hz

Rope A, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	6.6255	0.528094	0.079706	0.14669E-10
100.	5.9849	0.411533	0.068762	0.22863E-10
1000.	5.7568	0.334317	0.058074	0.18573E-09
10000.	5.2008	0.266940	0.051268	0.14830E-08
100000.	4.7625	0.300517	0.063100	0.16695E-07
1000000.	4.4191	0.303765	0.068739	0.16876E-06
9500000.	4.3046	0.316421	0.073507	0.16700E-05
30000000.	3.6555	0.304161	0.083207	0.50694E-05

Rope A, 120°C

FR	K1	K2	TAN DELTA	SIGMA
60.	21.033	53.21245	2.52997	0.17737E-08
100.	15.918	29.27719	1.83929	0.16265E-08
1000.	6.407	5.25332	0.81997	0.29185E-08
10000.	4.772	0.85355	0.17885	0.47419E-08
100000.	4.560	0.19611	0.04301	0.10895E-07
1000000.	4.209	0.15851	0.03766	0.88062E-07
9500000.	4.025	0.16402	0.04075	0.86569E-06

Rope B, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	7.6933	0.875021	0.113738	0.24306E-10
100.	7.5078	0.640551	0.085318	0.35586E-10
1000.	6.9986	0.444717	0.063543	0.24706E-09
10000.	6.0960	0.323863	0.053128	0.17992E-08
100000.	5.5494	0.346957	0.062522	0.19275E-07
1000000.	5.1731	0.392599	0.075892	0.21811E-06
9500000.	4.8283	0.406893	0.084272	0.21475E-05
30000000.	4.1279	0.411350	0.099650	0.68558E-05

Rope B, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	26.353	66.87852	2.53784	0.18577E-08
60.	23.345	57.07666	2.44490	0.19026E-08
100.	16.986	39.67288	2.33562	0.22040E-08
1000.	5.527	6.04871	1.09446	0.33604E-08
10000.	4.982	0.78675	0.15793	0.43708E-08
100000.	4.783	0.17227	0.03602	0.95707E-08
1000000.	4.691	0.11827	0.02521	0.65705E-07
9500000.	4.588	0.14783	0.03222	0.78019E-06

"Kevlar"Ropes, continued

Rope C, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	12.3266	1.799829	0.146012	0.49995E-10
100.	11.6037	1.436832	0.123825	0.79824E-10
1000.	9.5361	1.285998	0.134856	0.71444E-09
10000.	8.0059	0.964711	0.120500	0.53595E-08
100000.	6.8165	0.687531	0.100863	0.39196E-07
1000000.	5.6022	0.653690	0.116684	0.36316E-06
9500000.	4.9611	0.742388	0.149642	0.39182E-05
30000000.	3.9680	0.689153	0.173678	0.11486E-04

Rope C, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	36.390	160.49568	4.41044	0.44582E-08
60.	27.560	128.04948	4.64614	0.42693E-08
100.	23.815	89.23180	3.74686	0.49573E-08
1000.	7.197	12.34859	1.71576	0.68603E-09
10000.	5.520	1.78799	0.32393	0.99333E-08
100000.	4.989	0.39323	0.07881	0.21846E-07
1000000.	4.886	0.22794	0.04665	0.12663E-06
9500000.	4.441	0.27151	0.06114	0.14329E-05

Rope D, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	10.3523	1.177239	0.113718	0.32701E-10
100.	10.1137	0.912032	0.090178	0.50668E-10
1000.	9.4470	0.800575	0.084744	0.44476E-09
10000.	8.0265	0.950508	0.118422	0.52806E-08
100000.	6.4284	0.921320	0.143320	0.51184E-07
1000000.	5.0137	0.617431	0.123148	0.34302E-06
9500000.	4.5359	0.532482	0.117392	0.28103E-05
30000000.	3.6717	0.476469	0.129768	0.79412E-05

Rope D, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	34.260	127.21927	3.71333	0.35339E-08
60.	30.668	110.98825	3.61901	0.36996E-08
100.	22.945	87.83615	3.82816	0.48798E-08
1000.	7.334	10.14525	1.38328	0.56362E-08
10000.	5.576	1.54414	0.27692	0.85786E-08
100000.	5.013	0.33321	0.06646	0.18512E-07
1000000.	4.956	0.19092	0.03853	0.10607E-06
9500000.	4.625	0.24093	0.05209	0.12716E-05

"Mylar" 2-ply, corragated E. I. Dupont de Nemours and Co.

Frequency, MHz	K	D.F.
1	1.114	.00507
10	1.107	.00512
20	1.106	.00480
30	1.106	.00380

"Riston", exposed film E. I. Dupont de Nemours and Co.

Freq., MHz	1	10	100	1000	8515
K	3.31	3.12	2.97	2.85	2.77
D.F.	.042	.039	.0326	.0272	.0182

"Sclair" polyethylene Dupont of Canada
#8307-UV#5 24 GHz 22°C

K = 2.33 ± .02 D.F. = .00027 ± .00008

After 1500 hours in Atlas Weatherometer:

K = 2.30 ± .02 D.F. = .00041 ± .00003

"Tefzel" E. I. Dupont de Nemours and Co.

8.5 GHz 23°C K = 2.328 ± .011 D.F. = .0117

"Eccofloat" Emerson and Cuming

8.5 GHz 24 °C

EF38A, .6002 gm/cm^3 K = 1.8605 D.F. = .0128
EF38B, .4833 gm/cm^3 K = 1.8401 D.F. = .0121

"Eccofoam" HiK 625 Emerson and Cuming

24 GHz 24°C K = 6.0 D.F. = .045

"Stycast" 1.9 Emerson and Cuming
Sample from MIT, RLE

8.5 GHz 24°C K = 1.71 D.F. = .0055

"Esscolam" VI 8166 ESSCO
Sample from Raytheon

The temperature run was made with stacked disks at 8.5 GHz. The thickness shown is the stack height divided by the number of pieces and includes expansion due to trapped decomposition gases.

T°C	K	D.F.	Thick.,cm	Attan.,db	Insertion loss,db	Excess phase shift (deg.)
25	2.943	.0158	.063	.00789	.0587	.058
49	2.843	.0216	.0664	.0114	.0621	.065
73	2.835	.0292	.0669	.0155	.0665	.067
107	2.84	.047	.0677	.0252	.0779	.071
129	3.032	.0304	.0696	.0169	.0343	.086
163	3.129	.0764	.0676	.0410	.1112	.088
179	2.744	.0723	.0754	.0432	.1018	.090
198	2.748	.0569	.0784	.0355	.0988	.103
233	1.664	.0283	.1139	.0253	.0446	.091
245	2.165	.0251	.0909	.0180	.0559	.096
258	2.817	.0426	.0760	.0258	.0900	.098
272	3.02	.0527	.0731	.0307	.1042	.102
300	3.09	.0418	.0735	.0246	.1040	.107

"Lexan" General Purpose Grade, clear

General Electric

Frequency Run at 25°C

Freq., Hz	10^2	10^3	10^4	10^5	10^6	10^7	10^8	$3x10^8$	10^9	$3x10^9$	$8.5x10^9$
Lexan, clear											
κ	3.006	3.004	3.003	2.986	2.971	2.922	2.797	-	2.780	2.773	-
tan δ	.00056	.00085	.00152	.00405	.00849	.0111	.0103	-	.00643	.00515	-

"Lexan" 500, polycarbonate

R.T. 8.5 GHz K	D.F.
2.921	.00568

T°C	24 GHz K	D.F
24.4	2.881	.00625
62.3	2.872	.00734
68.3	2.871	.00739

"Noryl" (s)

General Electric

Frequency Runs at 25°C

Freq., Hz	10^2	10^3	10^4	10^5	10^6	10^7	10^8	$3x10^8$	10^9	$3x10^9$	$8.5x10^9$
Noryl N300											
κ	2.791	2.779	2.767	2.751	2.736	2.727	2.73	2.73	2.726	2.723	2.720
tan δ	.00324	.00357	.00388	.00367	.00322	.00252	.00241	.00266	.00356	.00436	.00575
Noryl RN300											
κ	3.144	3.117	3.081	3.048	3.020	2.982	2.976	3.065	3.062	3.057	3.050
tan δ	.00637	.00669	.00697	.00673	.00573	.00409	.00418	.00479	.00578	.00644	.00691
Noryl MN240											
κ	3.059	3.034	3.002	2.981	2.960	2.938	2.927	3.062	3.057	3.052	3.046
tan δ	.00702	.00649	.00581	.00469	.00385	.00289	.00280	.00320	.00380	.00365	.00324

Note: Electric field is perpendicular to faces of injection molded Noryl disks in the frequency range 10^2 to 10^8 Hz; at higher frequencies electric field is parallel to faces of disks.

"Noryl" undesignated

G.E. Sample from Sperry

24 °C

Freq., GHz	1	3	5	8.5	14
K	2.66	2.65	2.65	2.652	2.648
D.F.	.0020	.00313	.0036	.00396	.0058

PPO-534-801, polyphenylene oxide

General Electric

R.T. 8.5 GHz K	D.F
2.635	.00181

T°C	24 GHz K	D.F.
25	2.628	.00251
62.2	2.622	.00257
102.6	2.616	.00246
139.7	2.599	.00253
145.5	2.598	.00256
184.5	2.515	.00269
25	2.564	.00231

RTV's

General Electric

	24°C K	8.5 GHz D.F.
#60, red	3.736	.0172
#630, grey	3.016	.0199

Marco 28C — Grace Industries, Sample from Sperry

R.T. 8.5 GHz

	K	D.F.
Sample #1	2.929	.0164
Sample #2	2.880	.0114

Polyethylene with olive drab pigment — Hardigg Industries

24 GHz 23°C K = 2.29 D.F. = .00062

Radome fabrics — Hoover Industries

22 °C 8.5 GHz

Averages for three samples:

	K	D.F.	Thickness, cm
Grey	2.889	.0172	.059
White	2.895	.0174	.056

Polyethylene with 20 wt% gamma ferric oxide (<1μ) R.T. — Hellerbond

Frequency, GHz	1	1.685	2.45	3
Dielectric Constant	2.6605		2.6576	2.6520
Dielectric Loss Tangent	.0025		.0018	.0015
Magnetic Permeability	1.1163	1.113	1.1099	1.0860
Magnetic Loss Tangent	.01287	.0389	.0684	.0821

Hercules PC-072-2 polypropylene — Hercules

R.T. 8.5 GHz

K = 2.532
D.F. = .00217

24 GHz

T°C	K	D.F.
25	2.525	.00206
62.1	2.511	.00222
97.8	2.483	.00232
133.2	2.441	.00246
25	2.532	.00208

"Hycar" E4109 — Hycar, Samples from Raytheon

8.5 GHz

	T°C	K	D.F.		K	D.F.
Sample A	22	1.191	.0020	Sample B	1.178	.00196
	125	1.201	.0062		1.186	.0054
	25	1.190	.0021		1.175	.0020

"Thermocomp" DF1008 — Liquid Nitrogen Proc. Corp.

40% glass fiber reinforced polycarbonate 23°C

Freq. MHz	1	10	100
K	3.81	3.79	3.73
D.F.	.00704	.0084	.00864

LNP-OF-1006 polyphenylene sulfide — LNP

R.T. 8.5 GHz

K	D.F.
3.762	.00406

24 GHz

T°C	K	D.F.
25	3.709	.0055
58.6	3.722	.0058
85.8	3.715	.0063
107.5	3.712	.0067
135.8	3.677	.0078
25	3.706	.0053

LNP-GF-1006 polysulfone LNP

R.T. K	8.5 GHz D.F.	T°C	24 GHz K	D.F.
3.613	.00763	25	3.532	.0087
		61.8	3.529	.0102
		83.8	3.526	.0107
		112.	3.516	.0112
		126.8	3.506	.0105
		138.3	3.494	.0104

"Loctite" LI-260 24°C Loctite Corp.

Freq., Hz	100	1 k	10 k	100 k	1 M	10 M	8.5 G	14 G	24 G
κ'	4.568	4.459	4.319	4.093	3.716	3.356	2.409	2.404	2.394
κ"	.0851	.0888	.127	.200	.243	.230	.072	.0683	.0645
tan δ (D.F.)	.0186	.0199	.0295	.0489	.0653	.0684	.0299	.0284	.02695
σ mho/cm	4.74E-12	4.94E-1[illegible]	7.09E-10	1.11E-8	1.35E-7	1.28E-6	3.41E-4	5.31E-4	8.31E-4

Bondex 420 Loctite Corp.
Samples from Sperry

Sample #1 T°F	K	8.5 GHz D.F.
74	2.855	.0128
139	2.90	.0168
204	2.89	.0191

Sample #2 R.T. Freq. GHz	3	5	8.5	14
K	3.07	3.05	3.027	2.958
D.F.	.025	.026	.027	.0263

"Merlon" 1799 polycarbonate Mobay Chemical Corp.
oven dry

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	20.	2.873	0.001810	0.000630	0.20113E-13
3.3653	24.0	50.	2.877	0.001600	0.000556	0.44455E-13
3.3653	24.0	100.	2.895	0.001456	0.000503	0.80886E-13
3.3653	24.0	200.	2.897	0.001821	0.000629	0.20235E-12
3.3653	24.0	500.	2.894	0.002099	0.000725	0.58299E-12
3.3653	24.0	1000.	2.905	0.002241	0.000771	0.12450E-11
3.3653	24.0	2000.	2.904	0.002507	0.000863	0.27854E-11
3.3653	24.0	5000.	2.904	0.003329	0.001146	0.92465E-11
3.3653	24.0	10000.	2.904	0.004523	0.001558	0.25128E-10
3.3653	24.0	20000.	2.895	0.005672	0.001960	0.63022E-10
3.3653	24.0	50000.	2.867	0.008290	0.002891	0.23027E-09
3.3653	24.0	100000.	2.839	0.010191	0.003590	0.56618E-09
3.3653	24.0	1000000.	2.835	0.022129	0.007807	0.12294E-07
3.3553	24.0	300000.	2.876	0.015637	0.005438	0.26061E-08
3.3653	24.0	3000000.	2.845	0.026918	0.009462	0.44864E-07
3.3653	24.0	6000000.	2.893	0.027568	0.009529	0.91894E-07
3.3653	24.0	9500000.	2.904	0.029700	0.010228	0.15675E-06
3.3653	24.0	30000000.	2.899	0.029737	0.010256	0.49562E-06

"Merlon 1799 polycarbonate .15% water — Mobay

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	5.	2.939	0.003736	0.001271	0.10378E-13
3.3653	24.0	10.	2.941	0.002830	0.000962	0.15721E-13
3.3653	24.0	20.	2.934	0.002222	0.000757	0.24685E-13
3.3653	24.0	50.	2.935	0.001623	0.000553	0.45090E-13
3.3653	24.0	100.	2.933	0.001461	0.000498	0.81140E-13
3.3653	24.0	300.	2.930	0.001685	0.000575	0.28082E-12
3.3653	24.0	1000.	2.931	0.002294	0.000783	0.12743E-11
3.3653	24.0	3000.	2.931	0.003168	0.001081	0.52803E-11
3.3653	24.0	10000.	2.927	0.004844	0.001655	0.26908E-10
3.3653	24.0	20000.	2.925	0.006437	0.002200	0.71524E-10
3.3653	24.0	50000.	2.922	0.009453	0.003235	0.26260E-09
3.3653	24.0	100000.	2.920	0.012359	0.004233	0.68661E-09
3.3653	24.0	1000000.	2.896	0.024580	0.008489	0.13655E-07
3.3653	24.0	300000.	2.916	0.017691	0.006066	0.29485E-08
3.3653	24.0	3000000.	2.875	0.029417	0.010233	0.49029E-07
3.3653	24.0	9500000.	2.848	0.032089	0.011265	0.16936E-06
3.3653	24.0	30000000.	2.837	0.028328	0.009984	0.47214E-06

"Merlon 1799 polycarbonate .40% water — Mobay

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	30000000.	2.831	0.035201	0.012434	0.58668E-06
3.3653	24.0	9500000.	2.878	0.038360	0.013329	0.20245E-06
3.3653	24.0	6000000.	2.889	0.038060	0.013172	0.12687E-06
3.3653	24.0	16000000.	2.868	0.036307	0.012657	0.32273E-06
3.3653	24.0	3000000.	2.907	0.037947	0.013053	0.63245E-07
3.3653	24.0	300000.	2.952	0.023151	0.007842	0.38585E-08
3.3653	24.0	1000000.	2.928	0.032768	0.011191	0.18205E-07
3.3653	24.0	100000.	2.973	0.015012	0.005049	0.83403E-09
3.3653	24.0	50000.	2.951	0.011321	0.003837	0.31447E-09
3.3653	24.0	20000.	2.979	0.007393	0.002482	0.82140E-10
3.3653	24.0	10000.	2.987	0.005536	0.001853	0.30754E-10
3.3653	24.0	5000.	2.987	0.004109	0.001376	0.11414E-10
3.3653	24.0	2000.	2.982	0.003129	0.001049	0.34762E-11
3.3653	24.0	1000.	2.985	0.002618	0.000877	0.14544E-11
3.3653	24.0	500.	2.987	0.002519	0.000843	0.69976E-12
3.3653	24.0	500.	2.989	0.002411	0.000806	0.66963E-12
3.3653	24.0	200.	2.983	0.001958	0.000656	0.21751E-12
3.3653	24.0	100.	2.988	0.001946	0.000651	0.10814E-12
3.3653	24.0	100.	2.989	0.001831	0.000612	0.10170E-12
3.3653	24.0	50.	2.988	0.001829	0.000612	0.50805E-13
3.3653	24.0	20.	2.990	0.002070	0.000692	0.23000E-13

Napthalene $C_{10}H_8$ — MIT Material Science

	Freq., GHz	1	1.7	3	8.5	14
23°C solid	K				2.76	2.75
	D.F.				.00016	.00025
82°C liquid	K	2.53	2.53	2.53		2.47
	D.F.	.0001	.00022	.00052		.00115

Laminated polypropylene — MIT, Lincoln

24 GHz 24°C

Thickness, cm	K	D.F.
.415	2.27	.0010
.751	2.28	.0016
.866	2.27	.0037

RX-18 polymethylpentene — Mitsui

Samples from Naval Underwater Sys. Cen

Color	Freq., MHz	400	1000	3000	8515	21°C
None, 1977	K	2.132	2.130	2.127	2.125	
	D.F.	.00041	.00041	.00043	.00054	
None, 1978	K				2.133	
	D.F.				.00063	
Yellow	K				2.132	
	D.F.				.00062	
Red	K				2.1325	
	D.F.				.00062	
Dark Blue	K				2.134	
	D.F.				.00064	
Light Blue	K				2.130	
	D.F.				.00063	

TPX Natural — Mitsui

T°C	Freq., GHz	1	1.685	2.45	3	5	8.5
25	K	2.122	2.122	2.121	2.121	2.120	2.120
	D.F.	.00059	.00061	.00063	.00063	.00061	.000595
75	K			2.092			
	D.F.			.00067			
125	K			2.060			
	D.F.			.00071			
175	K			2.024			
	D.F.			.00076			

"Texin" 355D, natural, polyurethane — Mobay Chemical Corp.

Oven Dry

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	5.	5.827	0.493223	0.084651	0.13701E-11
3.3653	24.0	10.	5.720	0.321775	0.056253	0.17876E-11
3.3653	24.0	20.	5.624	0.233114	0.041447	0.25902E-11
3.3653	24.0	50.	5.562	0.177018	0.031828	0.49172E-11
3.3653	24.0	100.	5.498	0.158494	0.028829	0.88052E-11
3.3653	24.0	200.	5.466	0.172873	0.031628	0.19208E-10
3.3653	24.0	500.	5.325	0.170832	0.032080	0.47453E-10
3.3653	24.0	1000.	5.258	0.170086	0.032350	0.94492E-10
3.3653	24.0	2000.	5.204	0.169613	0.032595	0.18846E-09
3.3653	24.0	5000.	5.106	0.174394	0.034156	0.48443E-09
3.3653	24.0	10000.	5.026	0.169712	0.033764	0.94284E-09
3.3653	24.0	20000.	4.951	0.186249	0.037615	0.20694E-08
3.3653	24.0	50000.	4.892	0.197352	0.040345	0.54820E-08
3.3653	24.0	100000.	4.765	0.207658	0.043581	0.11537E-07
3.3653	24.0	1000000.	4.446	0.248577	0.055915	0.13810E-06
3.3653	24.0	300000.	4.624	0.223435	0.048325	0.37239E-07
3.3653	24.0	3000000.	4.238	0.261347	0.061662	0.43558E-06
3.3653	24.0	9500000.	4.059	0.285754	0.070401	0.15081E-05
3.3653	24.0	30000000.	3.825	0.329739	0.086210	0.54957E-05

"Texin" 355D .24% water Mobay

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	1000.	5.529	0.197005	0.035632	0.10945E-09
3.3653	24.0	300.	5.653	0.199805	0.035343	0.33301E-10
3.3653	24.0	100.	5.821	0.226719	0.038952	0.12595E-10
3.2653	24.0	3000.	5.409	0.200310	0.037031	0.33385E-09
3.3653	24.0	10000.	5.252	0.209153	0.039825	0.11620E-08
3.3653	24.0	20000.	5.157	0.215246	0.041739	0.23916E-08
3.3653	24.0	50000.	5.041	0.235391	0.046699	0.65386E-08
3.3653	24.0	100000.	4.946	0.236061	0.047723	0.13114E-07
3.3653	24.0	1000000.	4.569	0.270618	0.059230	0.15034E-06
3.3353	24.0	300000.	4.771	0.249592	0.052311	0.41599E-07
3.3653	24.0	3000000.	4.354	0.278557	0.063980	0.46426E-06
3.3653	24.0	9500000.	4.159	0.298530	0.071771	0.15756E-05
3.3653	24.0	100.	5.744	0.198500	0.034555	0.11028E-10
3.3653	24.0	50.	5.865	0.240356	0.040982	0.66766E-11
3.3653	24.0	20.	5.990	0.358001	0.059769	0.39778E-11
3.3653	24.0	10.	6.088	0.432141	0.070988	0.24008E-11

"Texin" 355D 1.14% water Mobay

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	30000000.	4.044	0.396381	0.098006	0.66063E-05
3.3653	24.0	9500000.	4.328	0.378195	0.087390	0.19960E-05
3.3653	24.0	6000000.	4.471	0.369416	0.082618	0.12314E-05
3.3653	24.0	3000000.	4.603	0.359783	0.078168	0.59964E-06
3.3653	24.0	400000.	5.151	0.317665	0.061671	0.70592E-07
3.3653	24.0	200000.	5.151	0.292836	0.056847	0.32537E-07
3.3653	24.0	100000.	5.708	0.280082	0.049068	0.15560E-07
3.3653	24.0	50000.	5.379	0.261052	0.048534	0.72515E-08
3.3653	24.0	20000.	5.573	0.244764	0.043922	0.27196E-08
3.3653	24.0	10000.	5.673	0.239800	0.042267	0.13322E-08
3.3653	24.0	5000.	6.185	0.242461	0.039204	0.67350E-09
3.3653	24.0	2000.	5.883	0.272124	0.046255	0.30236E-09
3.3653	24.0	1000.	5.964	0.325954	0.054652	0.18109E-09
3.3653	24.0	500.	6.095	0.425658	0.069834	0.11824E-09
3.3653	24.0	200.	6.246	0.691620	0.110727	0.76847E-10
3.3653	24.0	100.	6.407	1.150263	0.179529	0.63903E-10
3.3653	24.0	1000000.	4.887	0.346178	0.070842	0.19232E-06
3.3653	24.0	50.	6.660	1.667348	0.250363	0.46315E-10
3.3653	24.0	50.	6.640	1.947284	0.293261	0.54091E-10
3.3653	24.0	20.	7.157	4.148470	0.579605	0.46094E-10
3.3653	24.0	10.	7.634	7.581223	0.967773	0.42118E-10

Polysulfone board Norplex Division, UOP Inc.

$T^{o}C$	Freq., GHz	1	2.45	3	5	8.5	16	26
23	ε	2.981	2.978	2.977	2.975	2.960	2.950	2.945
	tan δ	.00393	.00459	.00469	.00524	.00539	.00560	.00573
50	ε	2.983	2.976	2.975	2.973	2.954	2.946	2.940
	tan δ	.00412	.00484	.00523	.00568	.00595	.00623	.00669
100	ε	2.984	2.982	2.980	2.976	2.953	2.945	2.940
	tan δ	.00458	.00548	.00585	.00634	.00704	.00734	.00760
150	ε	2.965	2.963	2.961	2.958	2.948	2.943	2.935
	tan δ	.99428	.00552	.00603	.00664	.00766	.00812	.00877
175	ε	2.948	2.946	2.945	2.941	2.934	2.928	2.921
	tan δ	.00370	.00500	.00546	.00623	.00762	.00872	.00968
150	ε	2.952	2.952	2.951	2.950	2.946	2.940	2.934
	tan δ	.00362	.00474	.00526	.00594	.00695	.00725	.00784
100	ε	2.953	2.952	2.951	2.949	2.942	2.936	2.931
	tan δ	.00357	.00458	.00489	.00547	.00629	.00660	.00680
50	ε	2.959	2.957	2.957	2.955	2.940	2.935	2.928
	tan δ	.00352	.00431	.00456	.00501	.00562	.00570	.00574
23	ε	2.959	2.958	2.956	2.954	2.937	2.935	2.930
	tan δ	.00321	.00408	.00419	.00467	.00524	.00518	.00510

Temperature Runs to the Liquid State at 2.45 Ghz on ten materials

Phillips Petroleum Co.

#52263
Type R-4 glass filled polyphenylene sulfide

T°C	K	D.F.	Thick.,cm
24.5	4.12	.00438	1.506
47	4.11	.00464	1.510
85	4.10	.00505	1.517
112	4.05	.0057	1.523
155	4.04	.0083	1.528
205	4.00	.0106	1.545
242	3.95	.0128	1.591

#52264
Type R-8 Glass and mineral filled polyphenylene sulfide

T°C	K	D.F.	Thick.,cm
24	4.33	.0059	1.574
64	4.35	.0088	1.579
92	4.38	.0112	1.578
112	4.34	.0126	1.579
143	4.29	.0132	1.590
178	4.26	.0134	1.599
209	4.11	.0134	1.654
229	3.97	.0128	1.732

#52265
Type R-10 glass & mineral filled polyphenenylene sulfide color cmpd.

22	4.88	.0037	1.513
55	4.89	.0040	1.517
76	4.90	.0042	1.519
99	4.92	.00514	1.522
118	4.91	.0059	1.521
152	4.90	.0076	1.528
171	4.90	.00816	1.531
210	4.88	.00936	1.547
240	4.83	.0105	1.573

#52266
Mineral filled polysulfone

23	3.37	.00517	1.670
67	3.38	.00595	1.676
93	3.38	.0064	1.680
120.6	3.33	.0062	1.683
153	3.23	.0065	1.709
176.5	2.91	.0097	1.908
206	2.55	.0224	2.377

#52267
polysulfone

23	3.06	.0049	1.678
50.4	3.07	.0055	1.680
89.6	3.04	.0060	1.690
113	3.00	.0057	1.700
157	2.91	.0060	1.735
174	2.62	.0084	1.884
204	2.30	.0209	2.34

#52268
Glass filled polybutylene terephthalate

24	3.49	.00645	1.664
54	3.47	.0110	1.676
87	3.47	.0203	1.688
114	3.48	.0352	1.705
145	3.50	.0448	1.726
175	3.65	.0772	1.776
197	3.94	.0937	1.772
235	4.24	.1152	1.818

#52269
polybutylene terephthalate

21.7	2.97	.0050	1.707
55.4	2.98	.0102	1.721
80.4	2.96	.0189	1.737
118.5	2.96	.0436	1.770
139	2.99	.0596	1.771
165	3.14	.0836	1.768
199	3.58	.1172	1.778
230	3.90	.1383	1.849

#52270
Glass filled polyacetal

21.6	3.26	.0292	1.728
49.5	3.49	.0309	1.761
87	3.61	.0649	1.785
118.5	3.75	.0568	1.799
146	3.99	.0511	1.812
179	4.24	.0491	1.943
199	4.04	.0445	2.098

Phillips' plastics, continued

#52271 polyacetal

T°C	K	D.F.	Thick.,cm
21	3.08	.0338	1.679
51.4	3.21	.0623	1.685
75	3.39	.0805	1.700
111	3.60	.0741	1.713
142	3.82	.0605	1.728
184	3.99	.0489	1.980
196	4.08	.046	1.755

#52272 polypropylene

T°C	K	D.F.	Thick.,cm
24.2	2.242	.00041	1.684
40.3	2.240	.00045	1.684
56	2.233	.00051	1.685
96	2.195	.00054	1.702
130.7	2.159	.00069	1.729
158	2.014	.00079	1.846
187	1.779	.00077	2.559

Cross-linked polyethylene CL-100 Phillips

Sample molded by Hardigg

24 GHz 23°C K = 2.229 D.F. = .00056

Ferrite Absorber Mixes with Dow Corning 184 2.45 GHz Raytheon

R-153 Ferrite, 60 wt%,

T°C	κ'	tan δ	μ'/μ$_o$	tan δ$_m$
22*	4.47	.0127	.9985	.491
24	4.35	.0123	1.014	.483
65	4.27	.0110	.940	.498
88	4.20	.0110	.901	.432
113	4.15	.0111	.837	.454
127	4.12	.0117	.822	.391
156	4.09	.0129	.817	.295
179	4.05	.0138	.813	.232
210	4.00	.0152	.840	.1535
241	3.95	.0180	.891	.052
259	3.92	.0190	.913	.033
290	3.87	.0212	.984	.0081
22	4.37	.0114	1.012	.494

Q-1 2.5:1 ratio

T°C	κ'	tan δ	μ'/μ$_o$	tan δ$_m$
22*	5.79	.0129	1.553	.8996
23	5.72	.0117	1.554	.894
62	5.63	.0112	1.502	.881
92	5.60	.0109	1.397	.903
95	5.60	.0109	1.386	.902
120	5.56	.0129	1.323	.911
128	5.53	.0137	1.309	.902
153	5.50	.0150	1.211	.924
184	5.46	.0159	1.130	.926
220	5.41	.0195	1.027	.941
239	5.37	.0214	1.012	.944
272	5.33	.0265	.896	.944
298	5.30	.0285	.797	1.060
21.7	5.90	.0127	1.480	.997

* in room temp. sample holder, other values in high temp. holder

"Plexiglass" V811-100, polymethylmethacrylate, oven dry Rhom & Haas Co.

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	30000000.	2.607	0.025432	0.009755	0.42386E-06
3.3653	24.0	9500000.	2.596	0.015776	0.006078	0.83264E-07
3.3653	24.0	3000000.	2.639	0.035585	0.013484	0.59308E-07
3.3653	24.0	300000.	2.681	0.051897	0.019354	0.86496E-08
3.3653	24.0	1000000.	2.664	0.040346	0.015143	0.22415E-07
3.3653	24.0	100000.	2.705	0.057965	0.021432	0.32203E-08
3.3653	24.0	50000.	2.742	0.067078	0.024462	0.18633E-08
3.3653	24.0	20000.	2.782	0.076921	0.027652	0.85468E-09
3.3653	24.0	10000.	2.849	0.082731	0.029037	0.45962E-09
3.3653	24.0	10000.	2.849	0.084718	0.029735	0.47065E-09
3.3653	24.0	5000.	2.889	0.096873	0.033535	0.26909E-09
3.3653	24.0	3000.	2.921	0.105489	0.036117	0.17582E-09
3.3653	24.0	1000.	3.000	0.127622	0.042541	0.70901E-10
3.3653	24.0	500.	3.032	0.142581	0.047028	0.39606E-10
3.3653	24.0	200.	3.100	0.159903	0.051582	0.17767E-10
3.3653	24.0	100.	3.168	0.147102	0.046427	0.81723E-11
3.3653	24.0	50.	3.255	0.157021	0.048238	0.43617E-11
3.3653	24.0	20.	3.408	0.166988	0.049002	0.18554E-11
3.3653	24.0	10.	3.494	0.172959	0.049503	0.96088E-12
3.3653	24.0	5.	3.569	0.174577	0.048921	0.48494E-12
3.3653	24.0	3.	3.636	0.138368	0.038050	0.23061E-12
3.3653	24.0	2.	3.731	0.143764	0.038530	0.15974E-12

"Plexiglass" continued

Rhom & Haas

.27% water

Molded by Eastman, from MIT ME

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	9500000.	2.596	0.034817	0.013414	0.18376E-06
3.3653	24.0	3000000.	2.654	0.041893	0.015783	0.69822E-07
3.3653	24.0	300000.	2.731	0.059684	0.021858	0.99473E-08
3.3653	24.0	1000000.	2.673	0.050151	0.018762	0.27862E-07
3.3653	24.0	100000.	2.755	0.067682	0.024566	0.37601E-08
3.3653	24.0	50000.	2.799	0.072824	0.026018	0.20229E-08
3.3653	24.0	20000.	2.843	0.079186	0.027854	0.87984E-09
3.3653	24.0	10000.	2.844	0.085537	0.030081	0.47520E-09
3.3653	24.0	3000.	2.910	0.103130	0.035441	0.17188E-09
3.3653	24.0	1000.	3.014	0.122055	0.040498	0.67808E-10
3.3653	24.0	1000.	3.014	0.121073	0.040165	0.67263E-10
3.3653	24.0	300.	3.081	0.143380	0.046533	0.23897E-10
3.3653	24.0	100.	3.220	0.171322	0.053137	0.95179E-11
3.3653	24.0	50.	3.289	0.150950	0.045894	0.41931E-11
3.3653	24.0	20.	3.407	0.161970	0.047547	0.17997E-11
3.3653	24.0	10.	3.539	0.172468	0.048727	0.95815E-12
3.3653	24.0	5.	3.632	0.172526	0.047507	0.47924E-12
3.3653	24.0	3.	3.658	0.147920	0.040435	0.27390E-12
3.3653	24.0	2.	3.797	0.140221	0.036928	0.15580E-12

1.5% water

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	10.	4.117	0.241926	0.058758	0.13440E-11
3.3653	24.0	10.	4.147	0.222634	0.053684	0.12369E-11
3.3653	24.0	20.	4.029	0.218649	0.054270	0.24234E-11
3.3653	24.0	50.	3.871	0.206526	0.053346	0.57368E-11
3.3653	24.0	100.	3.768	0.194061	0.051509	0.10781E-10
3.3653	24.0	200.	3.672	0.178341	0.048567	0.19816E-10
3.3653	24.0	500.	3.532	0.187601	0.053107	0.52111E-10
3.3653	24.0	1000.	3.454	0.169185	0.048989	0.93992E-10
3.3653	24.0	2000.	3.421	0.149799	0.04378[illegible]	0.16644E-09
3.3653	24.0	5000.	3.341	0.129041	0.038624	0.35845E-09
3.3653	24.0	10000.	3.290	0.116235	0.035327	0.64575E-09
3.3653	24.0	20000.	3.243	0.107560	0.033162	0.11951E-08
3.3653	24.0	50000.	3.191	0.098730	0.030953	0.27439E-08
3.3653	24.0	100000.	3.162	0.095400	0.030169	0.53000E-08
3.3653	24.0	500000.	3.068	0.085860	0.027987	0.23850E-07
3.3653	24.0	1000000.	3.029	0.078446	0.025898	0.43581E-07
3.3653	24.0	300000.	3.095	0.088521	0.028603	0.14754E-07
3.3653	24.0	3000000.	2.976	0.068226	0.022924	0.11371E-06
3.3653	24.0	9500000.	2.935	0.056405	0.019220	0.29769E-06
3.3653	24.0	30000000.	2.874	0.046728	0.016257	0.77880E-06

Richo 31001 polyurethane

Richo Plastics

Sample from Sperry

8.5 GHz   23°C   K = 2.979   D.F. =.0186

"Duroid" 5650 M-5 Rogers

8.5 GHz 21 °C

E perpendicular hot pressing direction K = 2.660 D.F. = .00242

E parallel " " " K = 2.558 D.F. = .00206

"Duroid" 5870 Rogers

8.5 GHz 21 °C E parallel to sheet

Thickness, inch	K	D.F.
1/16	2.42	.0019
.010	2.33	.0019

"Duroid" 5870M-1 Rogers

E perpendicular	HPD	2.443	.00207
E parallel	HPD	2.317	.00138

"Duroid" 5870M Rogers

In Room Temperature Sample Holder

		Rotation (degrees)	K	tan δ	
1 pc. full thickness	Face 1	0	2.630	.00287	E ⊥
		90	2.49[illegible]	.00237	E //
	2	0	2.632	.0031	E ⊥
		90	2.484	.00207	E //
	pc. 1/ pc. 2	0	2.592	.00283	E ⊥
		90	2.452	.00213	E //

Temperature run pc. 2/pc. 1

T^oC	E ⊥ K	tan δ	Thickness (cm)	E // K	tan δ
23.1	2.594	.00287	1.8583	2.462	.00256
50	2.592	.00306	1.8619	2.464	.00226
97	2.593	.00229	1.8670	2.460	.00203
160.	2.591	.00209	1.8681	2.452	.00199
205	2.[illegible]7	.00159	1.8722	2.425	.00129
246	2.571	.00182	1.8734	2.419	.00131
300	2.563	.00186	1.8805	2.405	.00131
350	2.395	.00239	2.0639	2.258	.00130
395	2.242	.00251	2.2581	2.159	.00100
468	2.088	.00289	2.5177	1.989	.00112
504	1.828	.00396	3.2300	1.722	.00339
528	1.095	.00155	4.7506	1.017	.0195

Polybutylenes — Shell

Room Temperature

Material #	Freq., GHz	.4	1	3	8.5
0200	K	2.265	2.265	2.264	2.264
	D.F.	.00029	.00026	.00025	.000275
8240	K	2.247	2.247	2.246	2.246
	D.F.	.00029	.00029	.00029	.00027

"Epon" 828 — Shell

100 pts resin, 80 pts hardener, 1 pt accelerator (ATC-3)

Sample from Brunswick

2.45 GHz 23°C

	K	D.F.
Sample #1, 30 min. after mixing, some bubbles	3.873	.198
5 hrs at 23°C, no bubbles	3.907	.214
47 hrs " " "	3.710	.152
Then 95 hrs at 40°C	3.310	.0756
Then 80 hrs at 60°C	3.165	.0533
Sample #2 Cured 1 hour at 105°C	3.14	.054

Various Plastics

All at 8.5 GHz, R.T.

Samples formed by Sperry

	K	tan δ
Cycloaliphatic resin	2.850	.0209
Polyester, casting, face 1	2.861	.010
face 2	2.850	.0086
" , Laminac	2.911	.0128
"Epon" 815, clear	2.60	.0074
white	13.9	.007
Ciba 279[illegible], clear	2.87	.0135
HY 917	12.9	.0095
D[illegible] 7521	13.0	.0045
Hetron 92FS	13.5	.0095
"Stafoam"	1.035	.00103
Richo 90-578 + 34-841	1.042	.00073
Rigid polyurethane foam	1.036	.00055
(Same at 1 GHz)	1.039	.00060

Rigid polyurethane foams:

Sample Designation	Length,cm	K	D.F.	gm/cm^3	(K-1)/den.
V6	2.35	1.1224	.00145	-	-
	3.55	1.1225	.00155	.096	1.28
V8	2.10	1.1580	.00214	-	-
	3.12	1.1591	.00229	.1189	1.34
V12	2.30	1.2872	.00390	-	-
	3.37	1.2906	.00362	.2056	1.41
V16	2.32	1.3271	.00456	-	-
	3.45	1.3252	.00460	.2398	1.35
V20	2.13	1.3948	.00455	-	-
	3.21	1.3895	.00445	.2941	1.32

"Tellite" RCP

8.5 GHz R.T.

Thickness, inch	K	D.F.
1/32	2.35	.0004
1/16	2.34	.00033

"Mindel" Stabilized basic polysulfone 1976 Union Carbide Corp.

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3484	25.5	1000000.	3.607	0.013891	0.003851	0.77170E-08
3.3484	25.5	9500000.	3.584	0.014416	0.004022	0.76082E-07
3.3484	25.5	30000000.	3.579			
3.3484	25.5	100000.	3.627	0.008946	0.002466	0.49697E-09
3.3484	25.5	10000.	3.639	0.008157	0.002242	0.45315E-10
3.3484	25.5	1000.	3.651	0.010085	0.002762	0.56027E-11
3.3484	25.5	100.	3.671	0.012933	0.003523	0.71852E-12
3.3484	25.5	50.	3.683	0.014043	0.003813	0.39008E-12
3.0945	50.0	50.	3.626	0.019363	0.005340	0.53787E-12
3.0945	50.0	100.	3.614	0.016199	0.004482	0.89995E-12
3.0945	50.0	1000.	3.590	0.011298	0.003147	0.62767E-11
3.0945	50.0	10000.	3.572	0.008738	0.002446	0.48544E-10
3.0945	50.0	100000.	3.558	0.007548	0.002121	0.41932E-09
3.0945	50.0	1000000.	3.538	0.010719	0.003030	0.59551E-08
3.0945	50.0	9500000.	3.520	0.013302	0.003779	0.70207E-07
3.0945	50.0	30000000.	3.512			
2.6799	100.0	30000000.	3.387			
2.6799	100.0	9500000.	3.390	0.009495	0.002801	0.50114E-07
2.6799	100.0	1000000.	3.425	0.006362	0.001858	0.35345E-08
2.6799	100.0	100000.	3.431	0.006911	0.002014	0.38395E-09
2.6799	100.0	10000.	3.441	0.009783	0.002843	0.54349E-10
2.6799	100.0	1000.	3.461	0.015383	0.004444	0.85459E-11
2.6799	100.0	100.	3.510	0.025626	0.007301	0.14237E-11
2.6799	100.0	50.	3.528	0.030249	0.008574	0.84025E-12
2.3632	150.0	50.	3.557	0.046422	0.013050	0.12895E-11
2.3632	150.0	100.	3.550	0.037887	0.010671	0.21049E-11
2.3632	150.0	1000.	3.504	0.022269	0.006356	0.12372E-10
2.3632	150.0	10000.	3.497	0.013270	0.003795	0.73723E-10
2.3632	150.0	100000.	3.458	0.008736	0.002526	0.48531E-09
2.3632	150.0	1000000.	3.456	0.005919	0.001712	0.32885E-08
2.3632	150.0	9500000.	3.436	0.006981	0.002032	0.36846E-07
2.3632	150.0	30000000.	3.424			
2.2314	175.0	30000000.	3.434			
2.2314	175.0	9500000.	3.444	0.006878	0.001997	0.36303E-07
2.2314	175.0	1000000.	3.458	0.007112	0.002056	0.39510E-08
2.2314	175.0	100000.	3.480	0.009930	0.002854	0.55169E-09
2.2314	175.0	10000.	3.492	0.016847	0.004825	0.93595E-10
2.2314	175.0	1000.	3.522	0.027321	0.007758	0.15178E-10
2.2314	175.0	100.	3.570	0.054329	0.015217	0.30183E-11
2.2314	175.0	50.	3.596	0.076612	0.021303	0.21281E-11

At 25°C after temperature run:

Freq., MHz	.5	1	2	3.5	6	9.5
Tan delta	.00336	.00370	.00369	.00350	.00339	.00326

Microwave data:

Freq., GHz	.15	.3	1	2.45	3	8.5
K	3.63	3.63	3.63	3.626	3.624	3.618
Tan delta	.00300	.00320	.00362	.00405	.00414	.00477

"Radel" polyphenylsulfone 1976 Union Carbide

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3428	26.0	1000000.	3.090	0.015613	0.005053	0.86739E-08
3.3428	26.0	9500000.	3.067	0.013474	0.004393	0.71113E-07
3.3428	26.0	30000000.	3.054	0.011929	0.003906	0.19881E-06
3.3428	26.0	100.	3.138	0.003346	0.001066	0.18588E-12
3.3428	26.0	60.	3.138	0.003189	0.001016	0.10630E-12
3.3428	26.0	50.	3.139	0.003530	0.001124	0.98045E-13
3.3428	26.0	1000.	3.130	0.003654	0.001167	0.20299E-11
3.3428	26.0	10000.	3.119	0.004941	0.001584	0.27451E-10
3.3428	26.0	100000.	3.111	0.009492	0.003051	0.52733E-09
3.0945	50.0	30000000.	3.034	0.016283	0.005366	0.27139E-06
3.0945	50.0	9500000.	3.056	0.014325	0.004687	0.75605E-07
3.0945	50.0	1000000.	3.070	0.012026	0.003917	0.66812E-08
3.0945	50.0	100000.	3.082	0.006560	0.002161	0.37002E-09
3.0945	50.0	10000.	3.088	0.004375	0.001417	0.24303E-10
3.0945	50.0	1000.	3.092	0.003760	0.001216	0.20886E-11
3.0945	50.0	100.	3.114	0.003895	0.001251	0.21641E-12
3.0945	50.0	50.	3.116	0.004514	0.001449	0.12538E-12
2.6799	100.0	50.	3.069	0.010899	0.003551	0.30274E-12
2.6799	100.0	100.	3.063	0.008544	0.002789	0.47466E-12
2.6799	100.0	1000.	3.064	0.004451	0.001453	0.24730E-11
2.6799	100.0	10000.	3.060	0.003849	0.001258	0.21385E-10
2.6799	100.0	100000.	3.032	0.004239	0.001398	0.23549E-09
2.6799	100.0	1000000.	3.025	0.006789	0.002244	0.37714E-08
2.6799	100.0	9500000.	3.022	0.011622	0.003346	0.61341E-07
2.6799	100.0	30000000.	2.986	0.014829	0.004967	0.24715E-06
2.3632	150.0	30000000.	2.997	0.011814	0.003943	0.19691E-06
2.3632	150.0	9500000.	3.003	0.008740	0.002910	0.46126E-07
2.3632	150.0	1000000.	3.002	0.005359	0.001785	0.29770E-08
2.3632	150.0	100000.	2.985	0.004182	0.001401	0.23236E-09
2.3632	150.0	10000.	3.008	0.004254	0.001414	0.23634E-10
2.3632	150.0	1000.	3.017	0.006471	0.002145	0.35949E-11
2.3632	150.0	100.	3.030	0.017789	0.005871	0.98825E-12
2.3632	150.0	50.	3.027	0.029222	0.009655	0.81172E-12
2.2314	175.0	1000.	2.996	0.010348	0.003454	0.57488E-11
2.2314	175.0	10000.	2.989	0.005134	0.001734	0.28802E-10
2.2314	175.0	100000.	2.985	0.004093	0.001371	0.22737E-09
2.2314	175.0	1000000.	2.983	0.004754	0.001594	0.26410E-08
2.2314	175.0	9500000.	2.981	0.007016	0.002354	0.37027E-07
2.2314	175.0	30000000.	2.959	0.009583	0.003239	0.15972E-06
2.2314	175.0	100.	3.001	0.047240	0.015739	0.26245E-11
2.2314	175.0	50.	3.016	0.078053	0.025882	0.21681E-11

At 25°C after temperature run:

Freq., MHz	.1	.5	1	2	3.5	6	9.5	16
Tan delta	.00355	.00502	.00539	.00562	.00553	.00513	.00489	.00446

Microwave data, as received, 26°C:

Freq., GHz	.15	.3	1	2.45	3	8.5
K	3.15	3.15	3.15	3.145	3.14	3.13
Tan delta	.00422	.00466	.00535	.00583	.00590	.00637

"Radel" 5000, batch 6 1977 Union Carbide

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3462	25.7	30000000.	3.225	0.015655	0.004855	0.26091E-06
3.3462	25.7	9500000.	3.249	0.017758	0.005466	0.93720E-07
3.3462	25.7	1000000.	3.280	0.019903	0.006068	0.11057E-07
3.3462	25.7	500000.	3.289	0.018275	0.005556	0.50765E-08
3.3462	25.7	3500000.	3.273	0.019114	0.005840	0.37166E-07
3.3462	25.7	6000000.	3.267	0.018102	0.005540	0.60341E-07
3.3462	25.7	2000000.	3.278	0.020383	0.006217	0.22647E-07
3.3462	25.7	100000.	3.314	0.012325	0.003719	0.68470E-09
3.3462	25.7	10000.	3.324	0.006728	0.002024	0.37377E-10
3.3462	25.7	1000.	3.333	0.005138	0.001542	0.28547E-11
3.3462	25.7	100.	3.337	0.004497	0.001347	0.24983E-12
3.3462	25.7	50.	3.340	0.004390	0.001315	0.12194E-12
3.3462	25.7	10.	3.344	0.004597	0.001375	0.25536E-13
3.0945	50.0	10.	3.373	0.003845	0.001140	0.21362E-13
3.0945	50.0	50.	3.367	0.004292	0.001275	0.11922E-12
3.0945	50.0	100.	3.365	0.004294	0.001276	0.23854E-12
3.0945	50.0	1000.	3.365	0.004493	0.001335	0.24961E-11
3.0945	50.0	10000.	3.361	0.005586	0.001662	0.31031E-10
3.0945	50.0	100000.	3.349	0.008392	0.002506	0.46620E-09
3.0945	50.0	1000000.	3.330	0.016008	0.004808	0.88935E-08
3.0945	50.0	3500000.	3.308	0.018926	0.005720	0.36800E-07
3.0945	50.0	6000000.	3.304	0.019846	0.006007	0.66154E-07
3.0945	50.0	9500000.	3.257	0.019724	0.006056	0.10410E-06
3.0945	50.0	30000000.	3.230	0.017414	0.005391	0.29023E-06
2.6799	100.0	30000000.	3.277	0.017188	0.005246	0.28647E-06
2.6799	100.0	9500000.	3.303	0.016053	0.004861	0.84724E-07
2.6799	100.0	6000000.	3.312	0.014460	0.004366	0.48201E-07
2.6799	100.0	3500000.	3.316	0.013026	0.003928	0.25327E-07
2.6799	100.0	1000000.	3.322	0.009055	0.002726	0.50305E-08
2.6799	100.0	100000.	3.329	0.005697	0.001711	0.31651E-09
2.6799	100.0	10000.	3.344	0.004510	0.001349	0.25054E-10
2.6799	100.0	1000.	3.346	0.003191	0.000954	0.17728E-11
2.6799	100.0	100.	3.346	0.004024	0.001202	0.22355E-12
2.6799	100.0	50.	3.348	0.004350	0.001299	0.12082E-12
2.6799	100.0	10.	3.352	0.004761	0.001421	0.26432E-13
2.3632	150.0	10.	3.337	0.008127	0.002436	0.45151E-13
2.3632	150.0	50.	3.326	0.005039	0.001515	0.13997E-12
2.3632	150.0	100.	3.325	0.004616	0.001388	0.25643E-12
2.3632	150.0	1000.	3.324	0.004200	0.001264	0.23331E-11
2.3632	150.0	10000.	3.318	0.005729	0.001726	0.31828E-10
2.3632	150.0	100000.	3.312	0.004871	0.001471	0.27064E-09
2.3632	150.0	1000000.	3.299	0.008096	0.002454	0.44980E-08
2.3632	150.0	9500000.	3.304	0.012436	0.003764	0.65635E-07
2.3632	150.0	30000000.	3.235	0.016230	0.005016	0.27050E-06
2.1135	200.0	30000000.	3.204	0.017966	0.005608	0.29944E-06
2.1135	200.0	9500000.	3.259	0.013099	0.004019	0.69133E-07
2.1135	200.0	1000000.	3.257	0.008395	0.002578	0.46642E-08
2.1135	200.0	100000.	3.274	0.011336	0.003463	0.62976E-09
2.1135	200.0	10000.	3.292	0.006291	0.001911	0.34950E-10
2.1135	200.0	1000.	3.312	0.007955	0.002402	0.44192E-11
2.1135	200.0	100.	3.314	0.022555	0.006806	0.12530E-11
2.1135	200.0	50.	3.318	0.037448	0.011285	0.10402E-11
2.1135	200.0	10.	3.335	0.129655	0.038878	0.72030E-12
2.0074	225.0	10.	4.254	1.648727	0.387569	0.91596E-11
2.0074	225.0	50.	3.708	0.455797	0.122933	0.12661E-10
2.0074	225.0	100.	3.579	0.345433	0.096506	0.19191E-10
2.0074	225.0	1000.	3.401	0.104960	0.030863	0.58311E-10
2.0074	225.0	10000.	3.312	0.044307	0.013377	0.24615E-09
2.0074	225.0	100000.	3.268	0.021754	0.006656	0.12085E-08
2.0074	225.0	1000000.	3.240	0.017423	0.005378	0.96792E-08
2.0074	225.0	9500000.	3.202	0.018617	0.005815	0.98257E-07
2.0074	225.0	30000000.	3.148	0.019601	0.006226	0.32668E-06

"Radel" 5000, continued

T°C	Freq.,GHz	1	1.685	2.45	3	5	8.515
25	K	3.195	3.190	3.186	3.182	3.170	3.155
	D.F.	.00547	.00533	.00594	.00618	.00646	.00654
75	K	3.200	3.193	3.187	3.183	3.171	3.157
	D.F.	.0065	.00646	.0067	.0074	.0080	.00757
125	K	3.197	3.191	3.182	3.178	3.169	3.1[illegible]5
	D.F.	.0074	.0072	.0077	.0086	.0094	.00875
175	K	3.194	3.190	3.181	3.177	3.166	3.141
	D.F.	.00805	.00795	.00835	.0092	.010	.0098
200	K	3.199	3.193	3.180	3.175	3.161	3.120
	D.F.	.0084	.0083	.0088	.0096	.0103	.0102

"Udell" P1700, Blend 63-72 1977 Union Carbide

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	10.	3.157	0.003836	0.001215	0.21313E-13
3.3653	24.0	50.	3.154	0.003579	0.001135	0.99417E-13
3.3653	24.0	100.	3.153	0.003723	0.001181	0.20683E-12
3.3653	24.0	100.	3.153	0.003624	0.001149	0.20131E-12
3.3653	24.0	1000.	3.139	0.004013	0.001279	0.22296E-11
3.3653	24.0	10000.	3.129	0.005502	0.001759	0.30567E-10
3.3653	24.0	100000.	3.119	0.010105	0.003240	0.56139E-09
3.3653	24.0	1000000.	3.095	0.015610	0.005043	0.86721E-08
3.3653	24.0	9500000.	3.080	0.015480	0.005025	0.81701E-07
3.3653	24.0	30000000.	3.070	0.009535	0.003[illegible]06	0.15892E-06
3.0945	50.0	30000000.	3.076	0.009711	0.003[illegible]57	0.16185E-06
3.0945	50.0	9500000.	3.085	0.015347	0.004975	0.80997E-07
3.0945	50.0	1000000.	3.096	0.011903	0.003844	0.66125E-08
3.0945	50.0	100000.	3.102	0.005793	0.001[illegible]68	0.32186E-09
3.0945	50.0	10000.	3.109	0.003908	0.001[illegible]57	0.21711E-10
3.0945	50.0	1000.	3.116	0.002879	0.000[illegible]24	0.15996E-11
3.0945	50.0	100.	3.123	0.002834	0.000907	0.15742E-12
3.0945	50.0	50.	3.126	0.002814	0.000900	0.78171E-13
3.0945	50.0	10.	3.127	0.002999	0.000959	0.16659E-13
2.6799	100.0	10.	3.116	0.005021	0.001611	0.27895E-13
2.6799	100.0	50.	3.110	0.003440	0.001106	0.95564E-13
2.6799	100.0	100.	3.108	0.003318	0.001068	0.18434E-12
2.6799	100.0	1000.	3.103	0.000283	0.000091	0.15746E-12
2.6799	100.0	10000.	3.098	0.003210	0.001046	0.17833E-10
2.6799	100.0	100000.	3.093	0.004087	0.0013[illegible]2	0.22706E-09
2.6799	100.0	1000000.	3.084	0.006812	0.002209	0.37843E-08
2.6799	100.0	9500000.	3.076	0.015220	0.004948	0.80328E-07
2.6799	100.0	30000000.	3.064	0.014844	0.004844	0.24740E-06
2.3632	150.0	30000000.	3.065	0.007800	0.002545	0.13000E-06
2.3632	150.0	9500000.	3.070	0.009555	0.003113	0.504[illegible]1E-07
2.3632	150.0	1000000.	3.078	0.005506	0.001789	0.30586E-08
2.3632	150.0	100000.	3.085	0.003295	0.001068	0.18304E-09
2.3632	150.0	10000.	3.089	0.003178	0.001029	0.17657E-10
2.3632	150.0	1000.	3.092	0.003490	0.001129	0.19390E-11
2.3632	150.0	100.	3.105	0.004438	0.001430	0.24657E-12
2.3632	150.0	50.	3.101	0.005444	0.001756	0.15121E-12
2.3632	150.0	10.	3.107	0.008402	0.002704	0.46679E-13
2.2314	175.0	10.	3.123	0.024379	0.007807	0.13544E-12
2.2314	175.0	50.	3.113	0.012030	0.003865	0.33417E-12
2.2314	175.0	100.	3.097	0.010603	0.003424	0.58908E-12
2.2314	175.0	1000.	3.089	0.004452	0.001441	0.24735E-11
2.2314	175.0	10000.	3.086	0.005330	0.001727	0.29611E-10
2.2314	175.0	100000.	3.075	0.002816	0.000916	0.15645E-09
2.2314	175.0	1000000.	3.065	0.003813	0.001244	0.21184E-08
2.2314	175.0	9500000.	3.033	0.010316	0.003401	0.54445E-07
2.2314	175.0	30000000.	3.023	0.012438	0.004114	0.20730E-06
2.1135	200.0	30000000.	3.066	0.018076	0.005895	0.30127E-06
2.1135	200.0	9500000.	3.079	0.016358	0.005312	0.86331E-07
2.1135	200.0	1000000.	3.102	0.019015	0.006130	0.10564E-07
2.1135	200.0	100000.	3.132	0.040219	0.012840	0.22344E-08
2.1135	200.0	10000.	3.211	0.105181	0.032752	0.58434E-09
2.1135	200.0	1000.	3.413	0.253232	0.074187	0.14068E-09
2.1135	200.0	100.	3.939	0.517254	0.131319	0.28736E-10
2.1135	200.0	50.	4.216	0.636457	0.150959	0.17679E-10
2.1135	200.0	10.	4.976	0.980310	0.196988	0.54462E-1[illegible]

"Udell" P1700, continued

T°C	Freq.,GHz	1	1.685	2.45	3	5	8.515
25	K	2.995	2.993	2.991	2.990	2.986	2.980
	D.F.	.00435	.0047	.0050	.00515	.0056	.00608
75	K	2.993	2.991	2.988	2.987	2.982	2.976
	D.F.	.00497	.0053	.00495	.00584	.00618	.00661
125	K	2.984	2.983	2.979	2.977	2.973	2.969
	D.F.	.00526	.0056	.00517	.00637	.00676	.00737
175	K	3.003	2.998	2.983	2.974	2.930	2.856
	D.F.	.0080	.0083	.00732	.00902	.0087	.00816

"Udell" P8000 (formerly "Mindel") 1977 Union Carbide

1000/T	T,DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3597	24.5	9500000.	3.650	0.015715	0.004306	0.82939E-07
3.3597	24.5	30000000.	3.620	0.013623	0.003763	0.22705E-06
3.3597	24.5	1000000.	3.680	0.016830	0.004573	0.93498E-08
3.3597	24.5	100000.	3.701	0.011566	0.003125	0.64255E-09
3.3597	24.5	10000.	3.722	0.009637	0.002589	0.53540E-10
3.3597	24.5	1000.	3.735	0.012112	0.003242	0.67286E-11
3.3597	24.5	100.	3.756	0.014206	0.003782	0.78920E-12
3.3597	24.5	50.	3.764	0.015360	0.004081	0.42667E-12
3.3597	24.5	10.	3.773	0.017836	0.004727	0.99091E-13
3.0945	50.0	10.	3.778	0.022700	0.006009	0.12611E-12
3.0945	50.0	50.	3.760	0.017612	0.004684	0.48922E-12
3.0945	50.0	100.	3.753	0.016253	0.004331	0.90296E-12
3.0945	50.0	1000.	3.745	0.012819	0.003423	0.71214E-11
3.0945	50.0	10000.	3.727	0.009887	0.002653	0.54927E-10
3.0945	50.0	100000.	3.710	0.008623	0.002324	0.47904E-09
3.0945	50.0	1000000.	3.695	0.010598	0.002868	0.58876E-08
3.0945	50.0	9500000.	3.651	0.015408	0.004220	0.81320E-07
3.0945	50.0	30000000.	3.623	0.011837	0.003267	0.19729E-06
2.6799	100.0	30000000.	3.631	0.012888	0.003549	0.21481E-06
2.6799	100.0	9500000.	3.666	0.012966	0.003537	0.68429E-07
2.6799	100.0	1000000.	3.695	0.008235	0.002229	0.45748E-08
2.6799	100.0	100000.	3.705	0.008922	0.002408	0.49569E-09
2.6799	100.0	10000.	3.726	0.012396	0.003327	0.68866E-10
2.6799	100.0	1000.	3.742	0.016426	0.004390	0.91257E-11
2.6799	100.0	100.	3.764	0.024341	0.006467	0.13523E-11
2.6799	100.0	50.	3.774	0.031256	0.008282	0.86823E-12
2.6799	100.0	10.	3.803	0.054660	0.014374	0.30367E-12
2.3632	150.0	10.	3.839	0.092246	0.024028	0.51248E-12
2.3632	150.0	50.	3.790	0.044838	0.011829	0.12455E-11
2.3632	150.0	100.	3.778	0.032946	0.008719	0.18303E-11
2.3632	150.0	1000.	3.744	0.020960	0.005598	0.11644E-10
2.3632	150.0	10000.	3.727	0.015101	0.004052	0.83893E-10
2.3632	150.0	100000.	3.706	0.012757	0.003442	0.70872E-09
2.3632	150.0	1000000.	3.677	0.008623	0.002345	0.47904E-08
2.3632	150.0	9500000.	3.652	0.013743	0.003763	0.72534E-07
2.3632	150.0	30000000.	3.614	0.017161	0.004749	0.28601E-06
2.2314	175.0	30000000.	3.603	0.009362	0.002599	0.15603E-06
2.2314	175.0	9500000.	3.633	0.013707	0.003772	0.72341E-07
2.2314	175.0	1000000.	3.682	0.017783	0.004830	0.98792E-08
2.2314	175.0	100000.	3.697	0.020848	0.005639	0.11582E-08
2.2314	175.0	10000.	3.726	0.026165	0.007022	0.14536E-09
2.2314	175.0	1000.	3.761	0.025904	0.006888	0.14391E-10
2.2314	175.0	100.	3.799	0.041062	0.010809	0.22812E-11
2.2314	175.0	50.	3.812	0.053381	0.014004	0.14828E-11
2.2314	175.0	10.	3.865	0.092537	0.023944	0.51409E-12
2.1135	200.0	10.	6.776	1.172523	0.173032	0.65140E-11
2.1135	200.0	50.	5.528	0.987350	0.178601	0.27426E-10
2.1135	200.0	100.	5.088	0.858599	0.168743	0.47700E-10
2.1135	200.0	1000.	4.221	0.401071	0.095028	0.22282E-09
2.1135	200.0	10000.	3.892	0.161689	0.041549	0.89827E-09
2.1135	200.0	100000.	3.767	0.073601	0.019537	0.40889E-08
2.1135	200.0	1000000.	3.683	0.036921	0.010025	0.20512E-07
2.1135	200.0	9500000.	3.617	0.030299	0.008377	0.15991E-06
2.1135	200.0	30000000.	3.571	0.022495	0.006300	0.37491E-06

"Udell" P-8000, continued

T°C	Freq.,GHz	1	1.685	2.45	3	5	8.515
25	K	3.590	3.569	3.556	3.550	3.538	3.527
	D.F.	.00410	.00420	.00428	.00432	.00438	.00435
75	K	3.575	3.558	3.547	3.542	3.527	3.515
	D.F.	.00471	.0049	.00503	.00504	.00496	.00480
125	K	3.562	3.545	3.532	3.527	3.511	3.486
	D.F.	.00495	.00518	.00538	.00555	.00582	.00576
175	K	3.543	[illegible]	3.517	3.510	3.495	3.472
	D.F.	.00520	.0056	.0060	.0063	.0067	.0069

Printed Circuit Boards — Union Carbide

Polyimide laminate, 11848-12-3

T°C	Freq., Hz	10	100	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
24.2	κ	5.141	5.122	5.075	5.044	4.972	4.898	4.789	4.68	4.65	4.57
	tan δ	.00577	.00510	.00459	.00553	.00994	.0156	.0194	.022	.0124	.0147
50	κ									4.67	4.58
	tan δ									.0138	.0196
100	κ									4.66	4.59
	tan δ									.0144	.0229
150	κ									4.66	4.593
	tan δ									.0144	.0263
175	κ									4.65	4.577
	tan δ									.0143	.0319
200	κ	7.560	5.797	5.191	4.988	4.929	4.830	4.759	4.71	4.64	4.516
	tan δ	.422	.1488	.0525	.0182	.00994	.00736	.00820	.0108	.0138	.0346
175	κ	5.519	5.149	4.971	4.874	4.815	4.75	4.717	4.68	4.63	4.54
	tan δ	.110	.0510	.0215	.0112	.00792	.0065	.00939	.0114	.0136	.0314
150	κ	5.325	4.983	4.884	4.814	4.765	4.730	4.675	4.63	4.61	4.55
	tan δ	.0534	.0265	.0127	.00835	.00624	.0070	.00924	.0113	.0130	.0255
100	κ	4.951	4.850	4.793	4.750	4.717	4.671	4.624	4.60	4.58	4.514
	tan δ	.0121	.00844	.0067	.00529	.00476	.0066	.0104	.0108	.0117	.0212
50	κ	4.823	4.725	4.709	4.684	4.660	4.609	4.544	4.50	4.55	4.451
	tan δ	.00547	.00691	.00429	.00411	.00557	.00795	.0109	.0098	.0097	.0169
25	κ	4.786	4.695	4.682	4.659	4.621	4.547	4.503	4.46	4.51	4.413
	tan δ	.00322	.00389	.00396	.00456	.0069	.00841	.0108	.0110	.0086	.0133

Polyolefin, crosslinked, 11848-12-2

T°C	Freq., Hz	10	100	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
24	κ	2.91	2.89	2.869	2.845	2.814	2.777	2.761	2.757	2.847	2.842
	tan δ	.00322	.00455	.0053	.00644	.00668	.00704	.00735	.0076	.00754	.00664
50	κ									2.860	2.828
	tan δ									.0103	.00807
100	κ									2.845	2.796
	tan δ									.0163	.0117
150	κ									2.877	2.778
	tan δ									.0236	.0170
175	κ									2.861	2.759
	tan δ									.0276	.0205
200	κ	3.229	3.046	3.002	2.884	2.790	2.755	2.688	2.59	2.778	2.756
	tan δ	.438	.0633	.0265	.0310	.0134	.0132	.0212	.0272	.0309	.0216
175	κ	3.226	3.216	3.045	2.923	2.872	2.812	2.731	2.65	2.779	2.757
	tan δ	.1324	.0334	.0345	.0183	.0131	.0177	.0211	.0232	.0248	.0200
150	κ	3.219	3.067	2.967	2.936	2.883	2.824	2.740	2.69	2.781	2.782
	tan δ	.0467	.0345	.0165	.0117	.0134	.0166	.0188	.0211	.0225	.0165
100	κ	3.012	3.005	2.978	2.931	2.874	2.821	2.766	2.72	2.805	2.801
	tan δ	.00247	.00417	.00859	.0115	.0128	.0137	.0139	.0136	.0130	.0104
50	κ	2.817	2.807	2.796	2.773	2.767	2.704	2.705	2.695	2.806	2.802
	tan δ	.00650	.00645	.00554	.00554	.00557	.00658	.00742	.0084	.00815	.00686
25	κ	2.824	2.820	2.814	2.805	2.789	2.767	2.743	2.73	2.804	2.802
	tan δ	.00200	.00251	.00294	.00336	.00402	.00510	.00618	.0066	.00632	.00536

Polysulfone P-1700, 11848-12-1

$T°C$	Freq., Hz	10	100	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
24	κ	3.203	3.186	3.173	3.157	3.152	3.141	3.094	3.06	3.043	3.025
	tan δ	.00111	.00132	.00157	.00240	.00448	.00810	.0106	.0097	.0063	.00652
50	κ									3.05	3.031
	tan δ									.00702	.00749
100	κ									3.05	3.029
	tan δ									.00785	.00878
150	κ									3.06	3.016
	tan δ									.0087	.01154
175	κ									3.03	2.983
	tan δ									0095	.0122
200	κ	5.48	4.30	3.59	3.35	3.21	3.16	3.13	3.08	3.02	2.977
	tan δ	.293	.186	.0923	.0413	.0199	.0094	.0087	.010	.0148	.0132
175	κ	3.22	3.22	3.20	3.14	3.12	3.10	3.09	3.07	3.01	2.977
	tan δ	.00929	.00756	.00720	.00952	.00342	.00371	.00411	.0064	.00962	.0139
150	κ	3.21	3.18	3.16	3.11	3.10	3.09	3.08	3.06	3.03	2.993
	tan δ	.00371	.00787	.00853	.00407	.00317	.00270	.00333	.0052	.00182	.0108
100	κ	3.09	3.08	3.08	3.08	3.08	3.07	3.07	3.05	3.01	2.977
	tan δ	.00073	.00064	.00057	.00065	.00094	.00158	.00303	.0042	.0055	.00783
50	κ	3.09	3.08	3.08	3.08	3.07	3.07	3.06	3.05	3.00	2.969
	tan δ	.00041	.00054	.00068	.00095	.00141	.00223	.00352	.0043	.0046	.00609
25	κ	3.097	3.088	3.085	3.080	3.073	3.063	3.056	3.03	3.00	2.966
	tan δ	.00046	.00066	.00096	.00134	.00160	.00256	.00384	.0039	.0041	.00519

At 24°C, 30 MHz, tan δ = .016

Polysulfone P-1720, 11848-12-2

$T°C$	Freq., Hz	10	100	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
24	κ	3.252	3.238	3.233	3.222	3.197	3.159	3.141	3.08	3.044	3.032
	tan δ	.00119	.00144	.00226	.00306	.00446	.00774	.00764	.0061	.00366	.00660
50	κ	3.23	3.22	3.21	3.20	3.20	3.17	3.13	3.08	3.050	3.034
	tan δ	.00127	.00098	.00125	.00162	.00272	.00555	.00795	.0077	.00656	.00757
100	κ	3.19	3.18	3.17	3.17	3.15	3.15	3.14	3.07	3.05	3.015
	tan δ	.00221	.00263	.00193	.00170	.00181	.00287	.00546	.0073	.0078	.00926
150	κ	3.27	3.22	3.19	3.15	3.13	3.11	3.10	3.07	3.04	3.006
	tan δ	.00491	.00827	.00777	.00518	.00433	.00379	.00451	.0068	.0086	.0115
24	κ	3.11	3.11	3.10	3.10	3.09	3.08	3.07			
	tan δ	.00061	.00081	.00103	.00160	.00237	.00326	.00389			
50	κ	3.12	3.09	3.09	3.09	3.09	3.08	3.07			
	tan δ	.00051	.00069	.00081	.00111	.00175	.00284	.00375			
100	κ	3.11	3.09	3.09	3.08	3.08	3.08	3.07			
	tan δ	.00111	.00083	.00073	.00084	.00119	.00196	.00319			
150	κ	3.24	3.20	3.75	3.13	3.11	3.08	3.08			
	tan δ	.00513	.00958	.00714	.00403	.00371	.00332	.00404			
	Freq., Hz										
150	tan δ	.00612	.00926								
175	κ									3.01	2.962
	tan δ									.0093	.0129
200	κ	4.84	3.84	3.46	3.28	3.20	3.16	3.13	3.08	3.02	2.942
	tan δ	.234	.1289	.0575	.0302	.01147	.00700	.00713	.0079	.0150	.0137
175	κ	3.26	3.22	3.19	3.15	3.14	3.11	3.10	3.06	2.95	2.917
	tan δ	.00679	.00703	.01132	.00551	.00306	.00338	.00396	.0060	.00966	.0123
150	κ	3.23	3.19	3.14	3.13	3.10	3.10	3.09	3.05	3.00	2.938
	tan δ	.00617	.0104	.00581	.00319	.00360	.00251	.00311	.0056	.00792	.0102
100	κ	3.11	3.11	3.10	3.10	3.10	3.09	3.09	3.04	2.99	2.935
	tan δ	.00078	.00062	.00058	.00066	.00088	.00151	.00271	.0042	.00362	.00785
50	κ	3.11	3.10	3.10	3.10	3.09	3.08	3.06	3.02	2.98	2.932
	tan δ	.00050	.00055	.00068	.00094	.00144	.00228	.00334	.0039	.00452	.00634
24	κ	3.110	3.104	3.100	3.100	3.098	3.087	3.081	3.04	2.98	2.932
	tan δ	.00045	.00073	.00098	.00135	.00195	.00269	.00348	.0035	.00408	.00517

At 200°C, 30 Hz, κ = 4.25, tan δ = .1796

Epoxy 2795/2793 with UV stabilizers — Union Carbide
Samples from MIT Lincoln Laboratory

3 GHz R.T.

Stabilizer	κ	tan δ
None	3.11	.0365
Benzotriazole	2.98	.0327
Substituted acrylonitrile	3.09	.0327
Benzidine malonate	3.14	.039
Benzophenone	3.10	.031

Polymer with tungsten wire reinforcement — AFML

25°C

Freq., Hz	κ	tan δ
100	8.91	.0117
1K	8.31	.0459
3K	8.02	.0400
10K	7.72	.0487
300K	6.10	.141
1M	5.71	.160
3.5M	4.69	.168
30M	3.75	.110
8.5G	3.034	.0253

Temperature run 8.5 GHz

T°C	κ	tan δ
23	3.032	.0241
94	3.142	.049
101	3.222	.077
130	3.294	.106
150	3.344	.137
170	3.376	.156
208	3.428	.184

Polyurethane Foam CPR 1057-6.24 — Upjohn

8.5 GHz R.T. K = 1.122 D.F. = .00241

IV. Liquids

Crude oil, low viscosity — MIT

T°C	T°F	Freq., Hz	10^2	10^3	10^4	10^5	10^6	5×10^6	1.6×10^7	10^9	2.45×10^9	3×10^9
58	136	κ	2.667	2.456	2.363	2.327	2.308	2.281	2.278	2.256	2.256	2.238
		tan δ	2.63	.332	.0541	.0102	.0038	.0050	.0073	.0074	.00495	.0052
		σ	3.9E-10	4.5E-10	7.1E-10	1.33E-9	4.87E-9	3.2E-8	1.5E-7	9.3E-6	1.5E-5	1.9E-5
22	72	κ	2.643	2.494	2.407	2.376	2.360	2.333	2.309	2.292	2.290	2.272
		tan δ	.408	.0742	.0172	.0061	.0076	.0106	.0115	.0035	.0028	.0029
		σ	6.E-11	1.E-10	2.3E-10	8.E-10	1.E-8	6.9E-8	2.3E-7	4.45E-6	8.7E-6	1.1E-5
-20	-4	κ	2.563	2.481	2.402	2.392	2.336	2.330	2.318	2.310	2.31	2.31
		tan δ	.0287	.0146	.0118	.0118	.00909	.00535	.00361	.0007	.0008	.0010
		σ	4.1E-12	2.E-11	1.5E-10	1.5E-9	1.2E-8	3.5E-8	7.4E-8	1.E-6	2.5E-6	3.8E-6

Crude oil, high viscosity — MIT

C536 (Alaskan type) 2%

T°C	T°F	Freq., Hz	10^2	10^3	10^4	10^5	10^6	5×10^6	1.6×10^7	10^9	2.45×10^9	3×10^9
60	140	κ	3.277	2.903	2.673	2.578	2.548	2.473	2.464	2.333	2.330	2.330
		tan δ	.285	.37	.0705	.0104	.0169	.019	.0173	.0080	.00584	.0076
		σ	5.2E-10	5.9E-10	1.E-9	2.9E-9	2.4E-8	1.3E-7	3.8E-7	1.E-5	1.85E-5	2.95E-5
28	82	κ	3.129	2.820	2.669	2.606	2.511	2.488	2.467	2.396	2.394	2.393
		tan δ	.397	.092	.0304	.0150	.0190	.0154	.0116	.0050	.0040	.0047
		σ	6.9E-11	1.4E-10	4.5E-10	2.[illegible]E-9	2.7E-8	1.E-7	2.5E-7	6.65E-6	1.3E-5	1.9E-5
-18	0	κ	2.811	2.670	2.591	2.535	2.495	2.492	2.489	2.37	2.37	2.37
		tan δ	.0421	.0275	.0178	.0126	.0076	.0050	.0032	.0022	.0021	.0025
		σ	6.4E-12	4.1E-11	2.6E-10	1.6E-9	1.E-8	3.4E-8	7.1E-8	2.9E-6	6.8E-6	1.E-5

Carbon tetrabromide | MIT Materials Science

1 MHz

	T°C	K	D.F.
Liquid	94	2.584	.00069
	102	2.563	.00091
Solid	25	2.468	.0002

Dioctalphthalate $C_{24}H_{38}O_4$ | MIT, Melcher

At 1 to 100 Hz, 23°C κ = 5.15 σ = 5.74E-12 mho/cm

Water-Hydrochloric Acid Solutions | MIT for JPL

8.515 GHz 24.1°C

Wt% Acid	κ'	κ''	σ	Wt% Acid	κ'	κ''	σ
0	63.5	63.7	.131	25	1.3	151	.713
5	39.5	119	.562	29	2.8	145	.685
10	12.0	162	.765	32	5.8	132	.625
18	-4.8	164	.777	37	9.4	124	.586

Water-Sulfuric Acid Solutions | MIT for JPL

8.515 GHz 24.9 ± .5 °C

Wt% Acid	κ'	κ''	σ
0	67.2	28.3	.134
1.11	64.0	37.3	.177
5.04	50.1	65.9	.312
10.08	32.0	97.7	.462
15.09	18.1	122	.579
20.15	6.4	140.5	.665
25.32	-0.4	152	.720
30.15	-4.1	157.5	.745
35.24	-0.2	157.4	.7445
40.38	3.8	150.7	.713
45.31	6.5	137.4	.650
50.38	17.3	127.3	.602
55.43	23.4	111.4	.527
60.39	25.5	91.9	.435
65.55	29.6	76.4	.362
70.61	24.2	56.2	.266
75.61	29.4	44.4	.210
80.49	29.0	36.1	.171
85.52	26.8	33.7	.159
90.55	28.0	35.6	.168
96.26	23.7	33.6	.159

8.515 GHz 22.8°C

Wt.% Acid	κ'	κ''	σ
0	67.0	29.4	.139
31.72	[illegible].3	153	.7225
33.7	[illegible]2	153.4	.726
35.23	3.2	153.3	.725
38.06	3.2	149	.704
40.80	6.4	145	.687
43.66	9.8	140.4	.664
47.22	11.3	130.8	.619
50.38	16.7	122	.578
52.74	21.8	119	.564
58.37	22.3	106	.502
64.69	32.0	78.6	.372
73.33	30.2	52.6	.249
84.59	29.8	32.7	.155
91.94	28.45	34.5	.163
95.87	26.4	34.6	.164
96.26	24.5	32.9	.159
96.61	23.4	31.1	.147
97.1	22.0	29.6	.140
97.22	21.8	29.9	.141

MATERIALS AND COMPANY INDEX*

* In this index Roman numerals refer to Tables of Dielectric Materials, Vols. IV, V and VI. P.R. refers to Tech. Rep. AFML-TR-82-39. Arabic number 8 refers to Tech. Rep. AFML-TR-74-250, Pt. II. Arabic number 9 refers to Tech. Rep. AFML-TR-74-250, Pt. III. This report is referenced by Arabic number 10 followed by page numbers.